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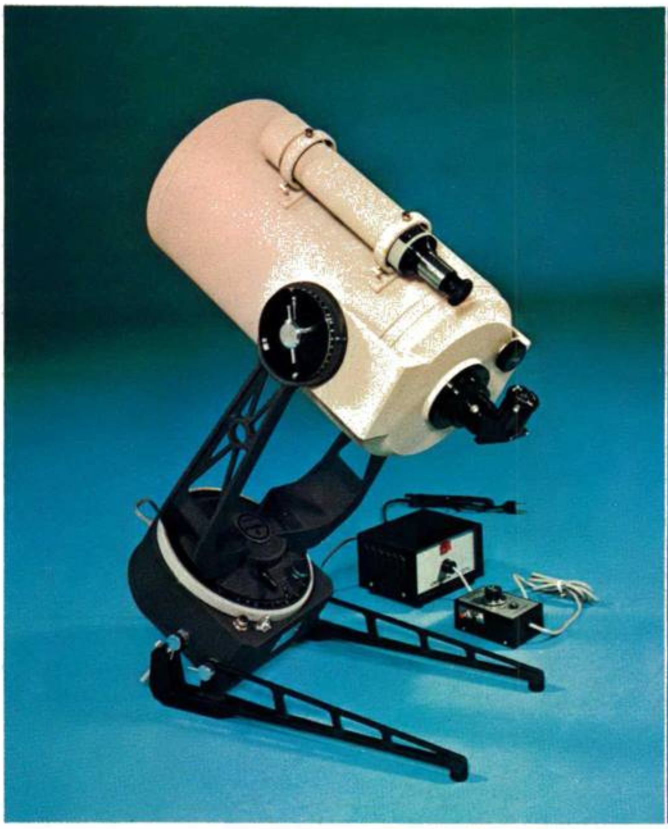

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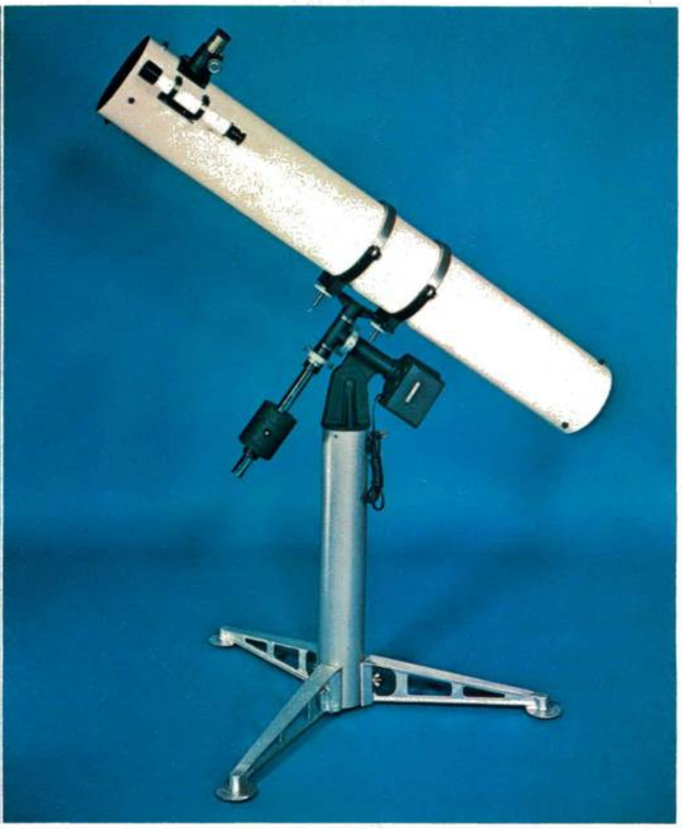

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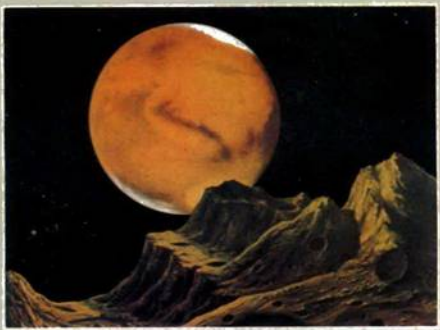

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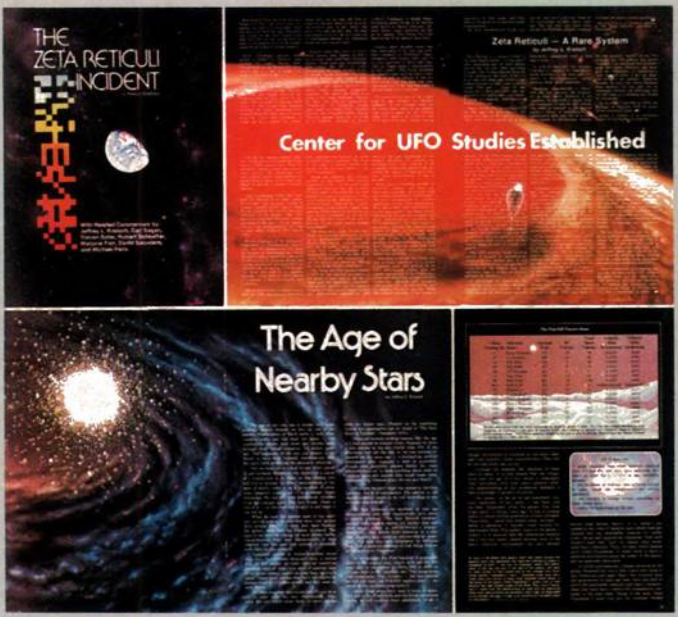
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Zeta Reticuli — A Rare System
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This exciting reprint combines, in one 32 page source, articles and commentary that appeared in ASTRONOMY which documented the astronomical implications of an alleged star map seen aboard a UFO by Betty and Barney Hill. While not offering incontrovertable proof that alien visitors to Earth live on a planet circling the star Zeta Reticuli, the astronomical detective work is persuasive. Commentary is provided by:

Jeffrey Kretsch, Robert Scheaffer, Marjorie Fish, David Saunders and Michael Peck. Full color, illustrated throughout, varnished cover.

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Photograph made by Orien A. Ernest using a home built cold camera shows clusters, nebulae and star clouds in true relationship to each other and to the constellation Sagittarius' teapot asterism. Better than a star atlas of this sky region, the photograph reveals in dramatic reds, golds and blues, objects you can easily find with your naked eye or binoculars. Varnished, suitable for framing, mailed in a heavy duty mailing tube, insured.

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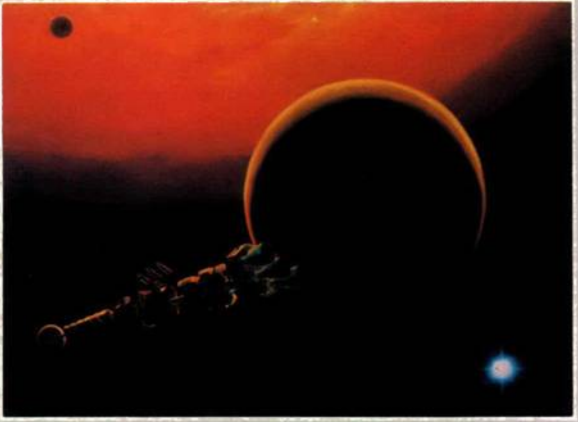
Exploration of Antares Star System



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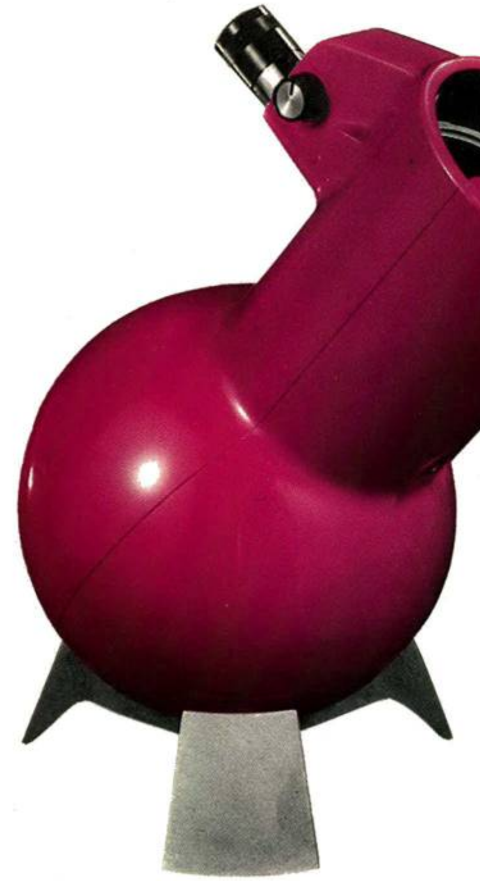

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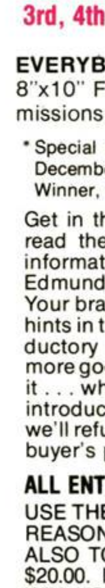

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ASTRONOMY

The World's Most Beautiful Astronomy Magazine

October 1976 Vol. 4, No. 10

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Cover

Fully color-corrected, Mars' surface shows a "blushing brick" soil coloration, scattered rocks, and orange-pink sky. This scene was taken shortly after landing, but the color test patches needed to insure truly accurate color could not be scanned by the camera immediately; thus, an inaccurate version of this picture was widely distributed. This month, ASTRONOMY searches Earth for Marslike places, takes a look at the Jovian satellites, and investigates some of the powerful techniques now employed by radio astronomers in their exploration of the universe. NASA photograph.

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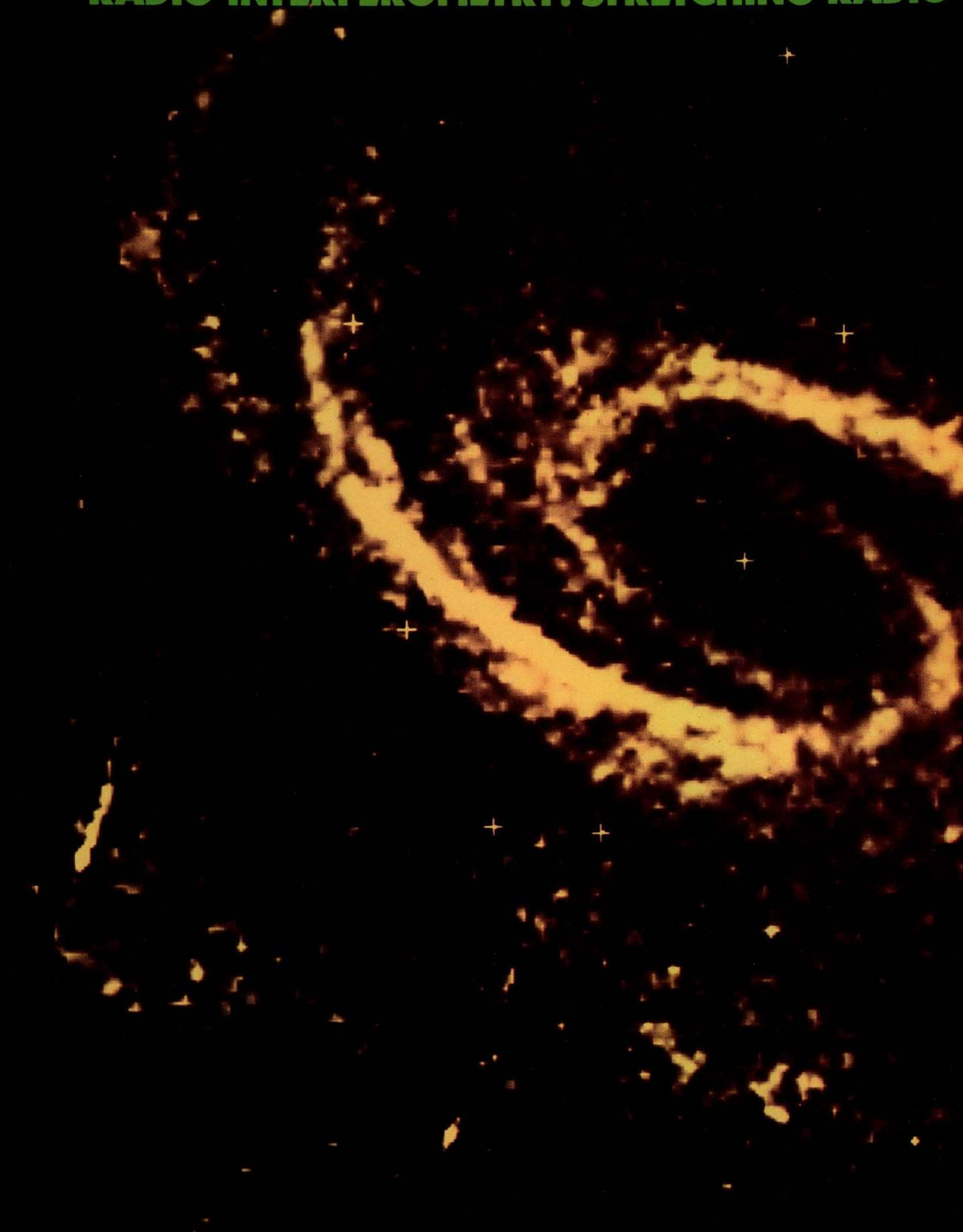
RADIO INTERFEROMETRY: STRETCHING RADIO



TELESCOPE PERFORMANCE

by Robert Sheaffer

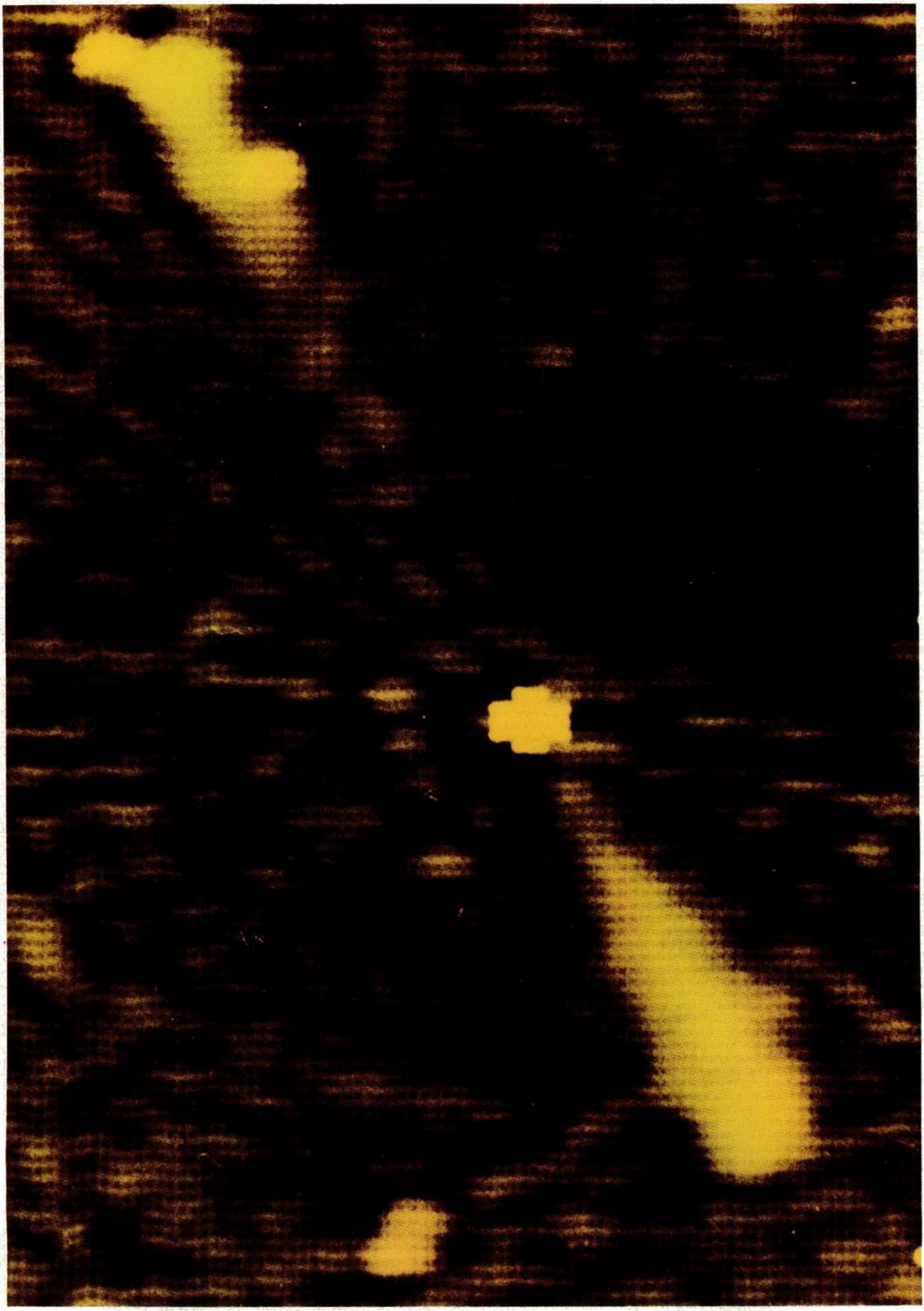
As seen by radio telescopes, the universe looks very different than it appears to our eyes. If our eyes were sensitive to radio wavelengths, we could see through walls and furniture, but would be unable to look through the holes in a metal chain-link fence! After growing accustomed to seeing things in this manner, we would develop a very different conception of the universe around us. So it should come as no surprise to learn that radio astronomers face problems unlike those encountered by optical astronomers. When looking through an optical telescope, atmospheric turbulence often makes serious work impossible. Light from the moon or artificial lights can spoil the image, and if clouds roll in, we might as well pack up and go to bed.

None of these things pose serious problems to the radio astronomer. Atmospheric turbulence is usually not a serious drawback, and radio observations can be made through thick clouds, in moonlight, or even full sunlight. But radio astronomers do not have all the advantages: The ignition system of a nearby automobile or aircraft can disable a large radio telescope. However, a more permanent and far more serious problem which severely limits all radio observation is that a radio telescope must be very large — even many miles in diameter — to match the resolution of a small optical telescope.

Resolution is a measure of the amount of observable detail using the telescope under ideal conditions; it's usually expressed in terms of the telescope's ability to show double stars as separate objects. The well-known double stars Albireo (in Cygnus) and Mizar (in the Big Dipper) are nowhere near the limit of resolution of even the most modest astronomical telescopes — in fact, a six inch telescope can resolve two stars separated by an angle of only one second of arc. The full moon, whose angular size is equivalent to an aspirin tablet held at arm's length, appears to be more than 1,800 seconds of arc in diameter. (A second of arc is 1/60 of a minute, which is 1/60 degree.)

A telescope's resolution is not limited only by the quality of the optics and by the steadiness of the atmosphere. A theoretically perfect telescope cannot resolve angles smaller than the limit determined by the diameter of the telescope's primary lens or mirror. Even in the best telescopes, most of the light from a star is imperfectly focused into a tiny disk known as the *Airy disk*, while a few percent of the rest of the light is spread into a series of faint rings around the disk. No details smaller than the Airy disk can ever be seen — the wave

By comparing radio photographs of this quality with optical photographs of the galaxy, astronomers will learn more about how stars and gas co-exist, and how galaxies form their spiral arms. The photograph shows the intensity of 21cm radio emission produced by atomic hydrogen gas; data was taken with the Westerbork Aperture Synthesis Radio Telescope in the Netherlands by A.H. Rots and W.W. Shane.



nature of light prevents our measuring exactly where the light came from. Even if the real apparent size of a star is only 1/1,000,000 second of arc, in a six inch telescope a star appears to have a false disk approximately one second of arc in diameter (the size of the Airy disk).

Only two options are available to decrease the size of this troublesome limitation: Build a larger telescope, or look at a shorter wavelength of light. In very large telescopes, atmospheric turbulence is a greater hindrance to resolution than the Airy disk, so little is gained in constructing telescopes beyond a certain size. The atmosphere that makes life possible on Earth also makes it impossible to look at shorter wavelengths of light, since short wavelengths don't penetrate the atmosphere. So, ground based astronomers long ago resigned themselves to making their observations within the limits imposed by the resolution of existing instruments.

In the radio region of the spectrum, resolution problems are far worse than in the optical; because radio waves are much larger than light waves, radio resolution is much poorer. Poor resolution seriously hampered the work of early radio astronomers as it is impossible to determine the position of radio objects without adequate resolution. In the 1940s, the pioneers of radio astronomy discovered a powerful radio source located somewhere in the constellation Cygnus. The object could not be identified on any existing star maps, because the resolution of the radio telescopes was so poor that nobody knew exactly where the object was. Not until 1952 was it possible to identify this unknown radio source as a distant galaxy, one billion light-years away.

Poor resolution obtained at radio wavelengths not only hinders the mapping of the positions of radio objects, but hides their shapes as well. Our galaxy is filled with hydrogen clouds of irregular shapes and sizes. Some of these clouds are highly visible, but others are dark without nearby stars to illuminate them. Since hydrogen clouds in space give off radio signals (at the 21cm wavelength), radio telescopes could detect them. But at radio wavelengths they could not be resolved, making it difficult to determine their size and distance. Radio astronomers knew they could not fulfill radio's potential until the resolution of radio telescopes was significantly improved.

The bane of radio astronomers has been the fact that as the wavelength increases, resolution deteriorates. Radio astronomers study waves ranging in length from about 1/10 inch (2mm) to over 30 feet (10m). A typical wavelength used by radio astronomers, the 21cm radio waves, is 350,000 times longer than the average wavelength of visible light. This means that a radio astronomer would need to build a telescope 350,000 times bigger or 33 miles (50km) in diameter just to equal the resolution at the 21cm wavelength of an ordinary six inch optical telescope.

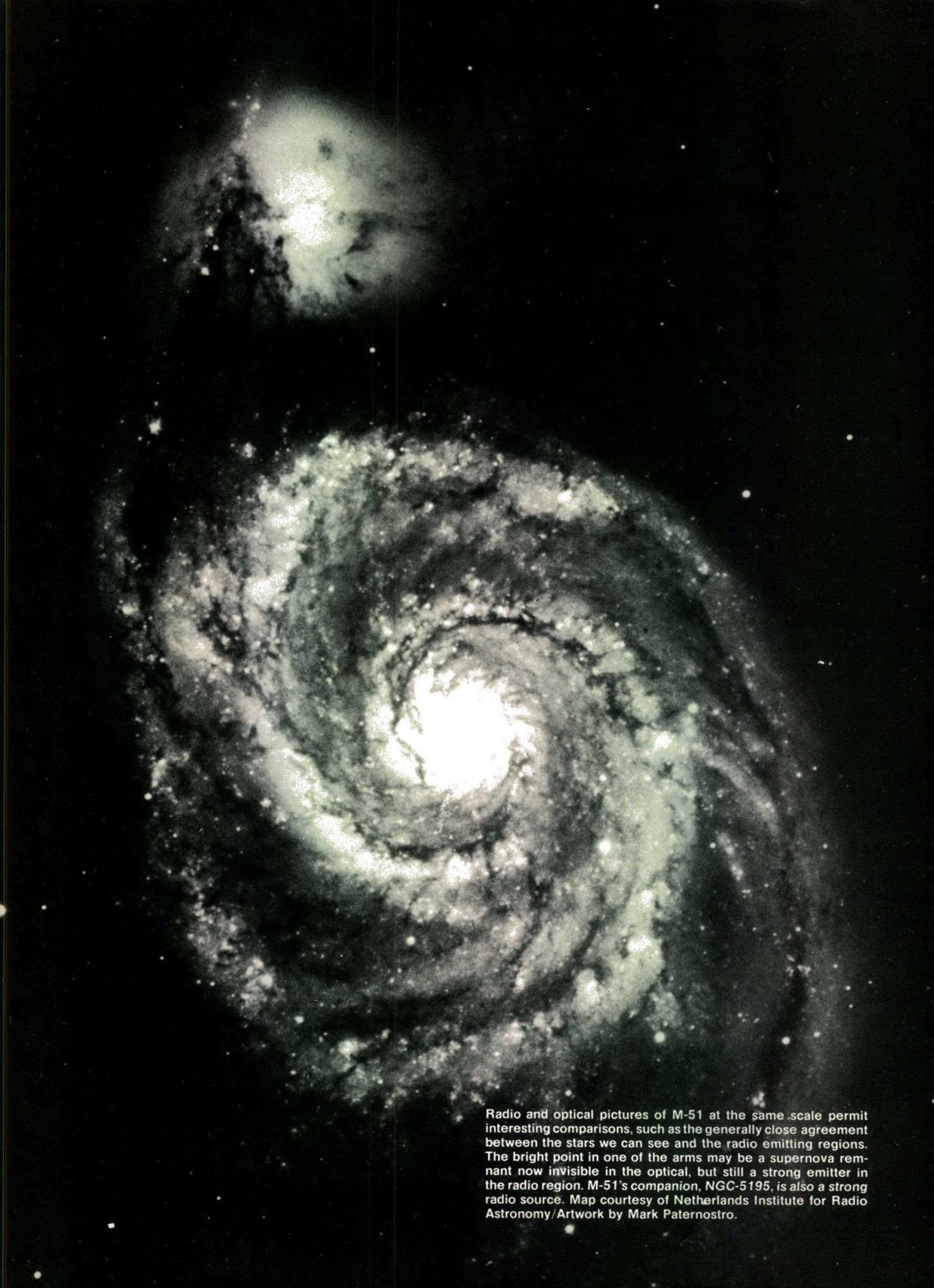
The radio galaxy 3C-236 is enormous: It stretches 18 million light-years between the tips of the giant gas clouds ejected from the central source, making it the largest object ever found in the universe. For comparison, our galaxy and the Andromeda galaxy are two million light-years apart. The jets of gas are thought to have been thrown out from the parent galaxy in some catastrophic explosion. Photograph courtesy of Netherland Institute for Radio Astronomy.

Although resolution can be improved by building larger telescopes there is a practical limit to their size. The largest, fully steerable radio telescope in the world (meaning that it can be pointed to any position in the sky) is the 250 foot telescope at Jodrell Bank, England. Despite its enormous size, its resolution at the 21cm wavelength is only 12 minutes of arc, meaning that it cannot pinpoint the positions of objects better than about 1/3 the apparent diameter of the full moon. Even the largest radio telescope in the world — the 1,000 foot dish built into a natural hollow at Arecibo, Puerto Rico — cannot do better at the 21cm wavelength than match the resolution of the human eye.

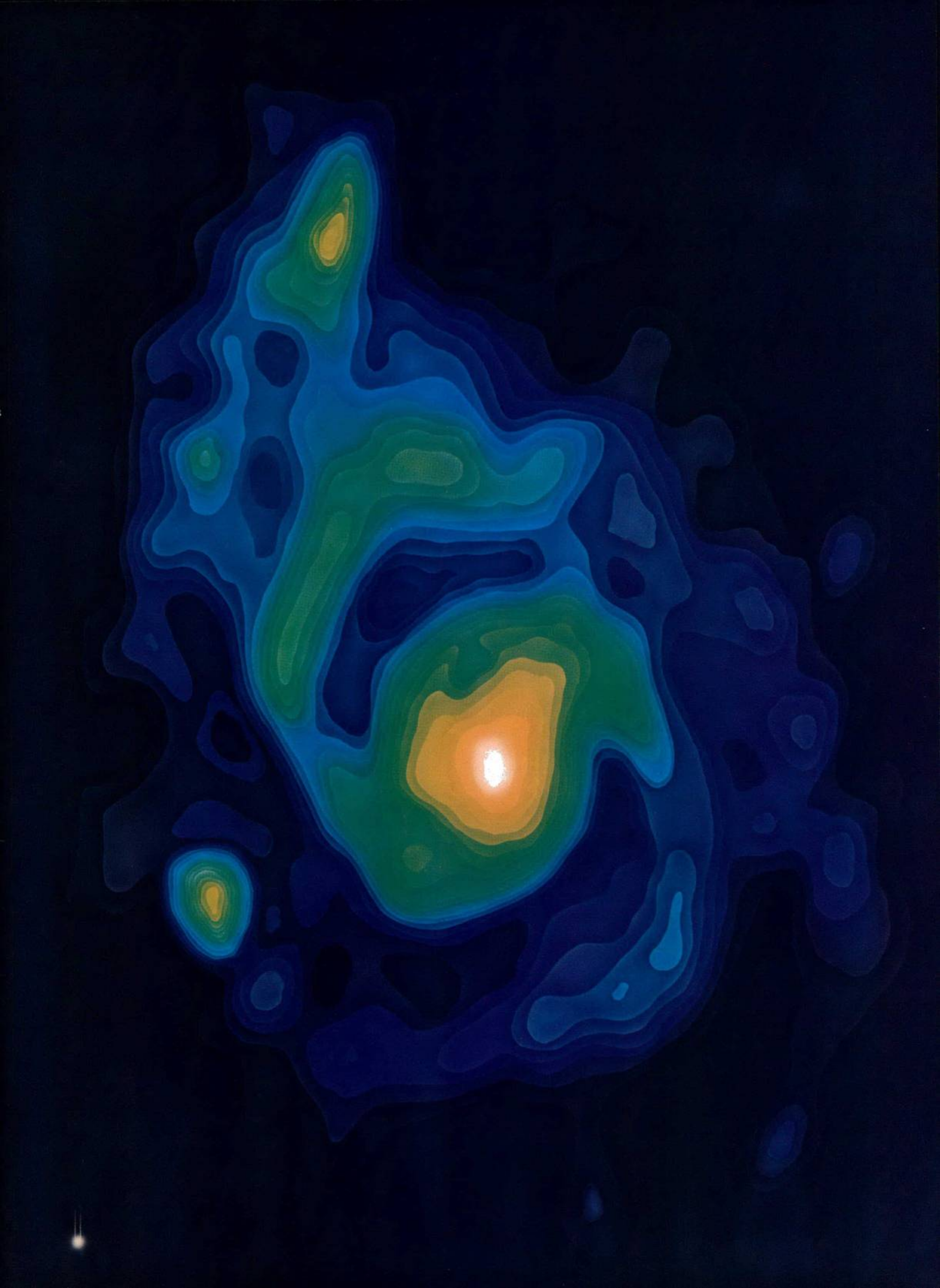
However, optical astronomers from time to time experimented with a technique known as *interferometry* to extend their telescopes' resolution. Although it has proved useful in special applications, interferometry is not in widespread use among optical astronomers. In radio astronomy, however, it has turned out to be of enormous value.

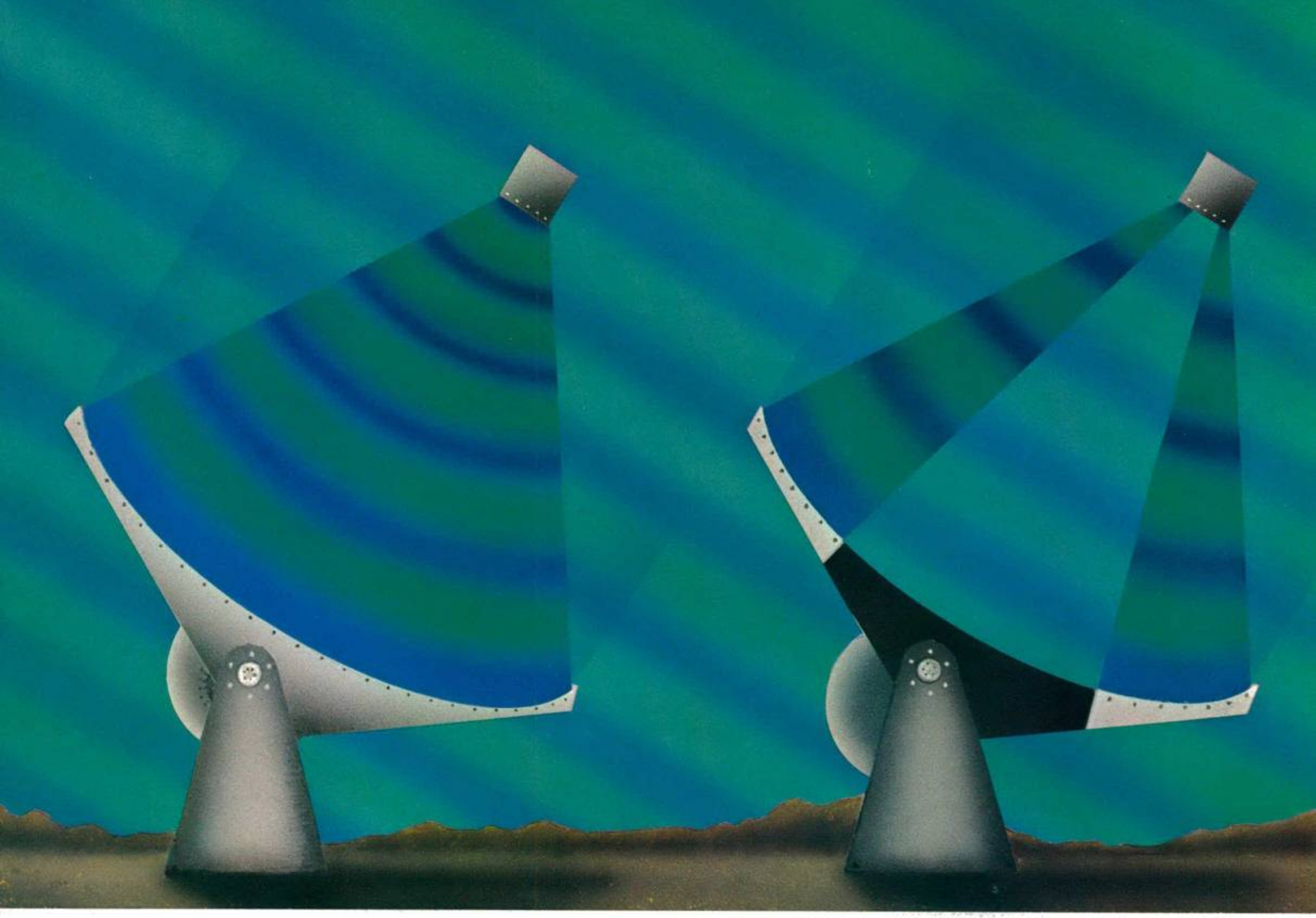
How does interferometry work? The basic idea is simple, although putting it into practice requires an enormous amount of complex mathematical calculations. A radio interferometer — which consists of two or more radio telescopes linked up by sophisticated electronics — collects electromagnetic waves originating from some distant celestial object and combines them. If the waves are exactly in phase, they will add together to make a stronger wave. If they are out of phase, they will completely cancel each other out. The resulting pattern is called an *interference pattern.* As Earth rotates, it carries the antennas of the interferometer along; thus the waves alternately reinforce and cancel each other. Waves which are in phase at one moment will be out of phase at the next, due to this constant motion. The changes in the interference pattern contain information about the size of the source, and are usually recorded for later analysis.

The first highly important piece of information that the interference patterns contain is a key to the exact position of the radio object. Two antennas placed a mile apart can determine positions as accurately as a gargantuan dish a mile across. The interference pattern produced by the mixing of the waves rises and falls as the rotation of Earth moves the two antennas of the interferometer. One of the peaks of the interference pattern is higher than all the others. When this happens, the radio object is exactly perpendicular to a line drawn through the two antennas. By recording the time of the central maximum, radio astronomers can determine the exact



Radio and optical pictures of M-51 at the same scale permit interesting comparisons, such as the generally close agreement between the stars we can see and the radio emitting regions. The bright point in one of the arms may be a supernova remnant now invisible in the optical, but still a strong emitter in the radio region. M-51's companion, *NGC-5195, is also a strong* radio source. Map courtesy of Netherlands Institute for Radio Astronomy/Artwork by Mark Paternostro.





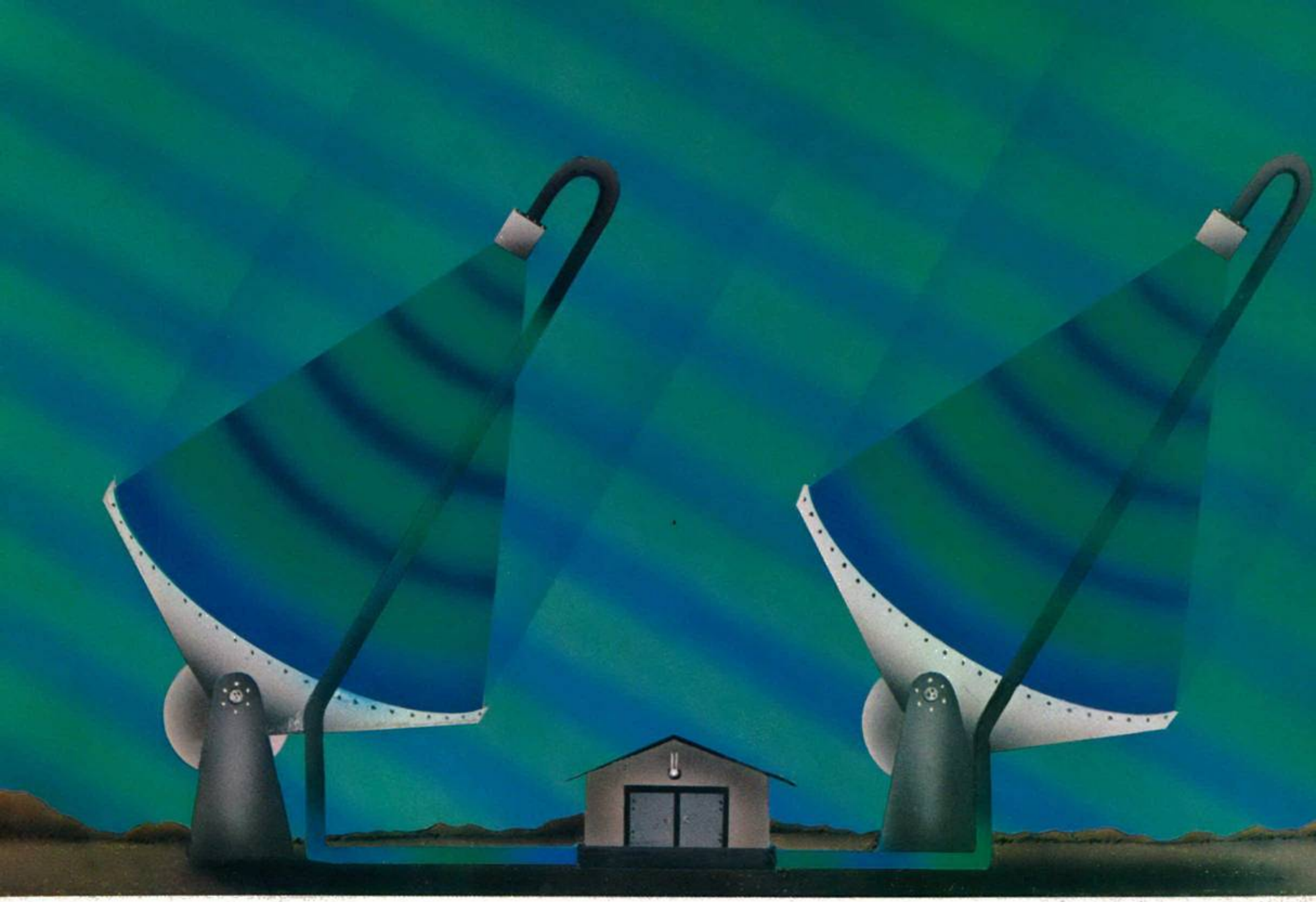
The separation between beams of radio waves determines the resolution of a radio telescope. Here, radio waves from a distant point source illuminate two antennas — one complete, and the other missing its center. If incoming waves from a slightly different direction approached the antennas, their interference would change by the same amount, giving both the ability to separate the sources. Artwork by Mark Paternostro.

moment when the object crosses a given point in the sky. But to determine the object's precise position in the heavens requires at least one more antenna. An interferometer using a pair of antennas carefully lined up on an east-west line will tell us the exact moment that the object crosses the meridian. This tells us its right ascension, or the object's celestial longitude. But we do not know its position until we determine one more value: the object's declination, or celestial latitude. So a third antenna is needed, not in line with the other two. The interference pattern resulting from combining the output of antennas one and three (or two and three) will yield the object's declination. This is one reason that many interferometers are designed to have more than just two antennas.

The second use of inteferometry is to determine the size and shape of radio objects. If the object emitting radio waves is a *point source* — a starlike object of no appreciable shape or size — then its radio waves will arrive exactly in step, and its interference patterns will be sharp and clear. But if the celestial object is bigger than a point source, the waves will no longer combine so neatly; they will not arrive in perfect step, because they are not all coming from exactly the same point. The interference pattern produced will not be so sharp and distinct; the waves will not cancel each other out completely. By varying the direction and the spacing of the interferometer, we can explore the shape and size of the radio object, eventually obtaining a rough idea of what the object would look like if you could see at radio wavelengths.

Practically any information that can be obtained by using a giant radio telescope as large as the baseline of the interferometer can be obtained by an interferometer instrument. The interferometer is slower and much more complicated, however. Interferometers are inexpensive, and astronomers are thus glad to have them. Amazingly, two small radio telescopes placed 1,000 miles apart (if given enough time and computer sophistication) can achieve the full resolution of a 1,000 mile diameter radio telescope. The future possibilities of interferometry seem almost limitless.

One promising new application of interferometry is *aperture synthesis*. As the name suggests, aperture synthesis is a way to synthesize, or imitate, the performance of a radio telescope of exceedingly large aperture, using smaller radio antennas. Aperture synthesis goes far beyond simple interferome-



To be combined, radio waves need not come from a single dish; signals from dishes separated by many miles can be sent through cables to a central point to be combined. The radio telescope then becomes known as an interferometer, and has an ability to separate sources as if it were a single giant dish whose size was equal to the spacing between the interferometer antennas. Artwork by Mark Paternostro.

try, yielding not only excellent measurements of positions and sizes of radio objects, but producing an actual radio "picture" of the object being examined.

A great deal of mathematical sophisitication is required to perform aperture synthesis. Martin Ryle, its inventor, pointed out in his Nobel Prize acceptance speech that although the idea of aperture synthesis occurred to him as early as 1954, he did not succeed in putting it into operation for almost 10 years because "at that time there were no computers with sufficient speed and storage capacity" to process the data. However, computers have dramatically increased in speed and effectiveness, and aperture synthesis is now a valuable technique for exploring the radio universe. How does it work?

Imagine a giant radio dish one mile in diameter. Radio waves falling on the dish produce a radio picture of the object being examined. Replace the giant dish with several smaller radio telescopes which can be moved around to various positions inside a one mile circle. If the smaller antennas are moved around long enough, they eventually will cover every point within the one mile circle. The missing part of the mile wide aperture will ultimately be "filled-in", even though the entire aperture was never present at the same time. Obviously, this method is troublesome and time consuming, but it has proved an exceedingly valuable tool for radio astronomy. Fortunately, it is not necessary for the phantom aperture to be 100 percent "filled-in" to make aperture synthesis work. Even a partial aperture can produce satisfactory images, as anyone who has ever looked through a Newtonian telescope — which has its mirror partially blocked by a secondary mirror — can verify. Another factor making aperture synthesis a little less impractical than it appears at first is the radio astronomer's "best friend" — the rotation of Earth. Although it would prove exceedingly difficult to constantly move around precision radio telescopes 100 feet in diameter, radio astronomers take full advantage of the fact that Earth is moving and carrying the massive telescopes used in aperture synthesis.

Aperture synthesis is used to obtain highly detailed "pictures" of many radio sources, and the results have been significant: Most of the radio objects outside our galaxy appear not as a single unresolved object, but as two rather large objects some distance apart. Although the explanation is

continued on page 16

Radio Photographs

by

Gerrit L. Verschuur

The universe is full of objects that emit considerable amounts of energy at radio wavelengths, including nebulae, galaxies, supernovae and quasars. The study of such objects falls in the domain of the radio astronomer. Unlike his counterpart — the optical astronomer — who can obtain photographs of visible objects, the radio astronomer cannot "see" the object of study. To produce a radio picture of a celestial object, the radio astronomer must combine a large amount of radio telescope-garnered data.

What makes his task so difficult is the fact that a radio telescope collects signals from only one "point" of the sky at a time, while an optical telescope and camera system easily records the light from thousands of sources simultaneously. To scan an equivalent portion of the sky, the radio astronomer needs to sequentially focus the radio telescope at many different points of the sky within the desired area. This time-consuming mapping program generally produces a set of numbers corresponding to the intensity of the radio energy being emitted by each location in the sky. The data is plotted, and contour lines (like those used in geographical maps to designate elevation) are drawn to indicate the levels of radio energy received.

In order to quickly and effectively map an area of the sky, several radio telescopes can be interlinked and the complex signal pattern, otherwise impossible to interpret, is collected and fed to a computer for subsequent processing. Recently, computers have been programmed to display (on a television screen) the radio map as an optical picture of what the radio source "looks" like to the "radio eye". These pictures, when photographed from the display screen, are called "radiographs" and present an exciting new view of celestial objects.

Just as optical photographs are only part of the way astronomers gather information, so radiographs are merely one way of obtaining an overall impression of what the radio source looks like. More effective in displaying the data than contour maps, radiographs allow the untrained eye to see what is important. Pioneered by scientists at the Westerbork Observatory in the Netherlands, their production is part of the data reduction systems used by several of the world's largest radio telescope *interferometers*. (An interferometer is a group of telescopes linked together to simulate a larger one.)

Comparative studies of radiographs and optical images of the same object lead to some insight into the nature of emitting regions. In the case of galaxies, light and radio emissions are produced in different ways. The light is generated by the billions of galactic stars while the radio signals are produced in interstellar regions, where electrons traveling at nearly the speed of light spiral about magnetic fields (known as *synchroton radiation)*. Since the bright stars in spiral galaxies lie in distinct spiral patterns, it is important to know if the magnetic fields and the electrons involved in the radio emission process are confined to the spiral arms. The question is unanswered for the Milky Way, since we are located within it and lack a method of determining the distance to the regions emitting radio waves.

Radio maps of the galaxy M-51 suggest that radio wave production is confined to its spiral arms. Plotted peaks and valleys indicate maxima and minima in the recorded radio emissions, while the highest radio contours lie along M-51's sprial arms. A radio emitting bridge to a companion galaxy, NGC-5195, also appears. A number of other distant radio sources, including one which is believed to demarcate the site of an old supernova explosion, can be seen in the map. These auxiliary radio sources appear as sets of concentric contour lines indicating peaks in emission (see pages 10 and 11).

Radiographs of some Milky Way nebulae (such as supernovae remnants or emission nebulae) demonstrate that radio and optical emissions are closely correlated in position and structure. This data, together with information about the nature of the light and radio signals, tells the astronomer that the sources of the emissions are identical. Both are produced by electrons spiraling about highly compressed magnetic fields in the regions of the shell of matter still expanding away from the site of the explosion.

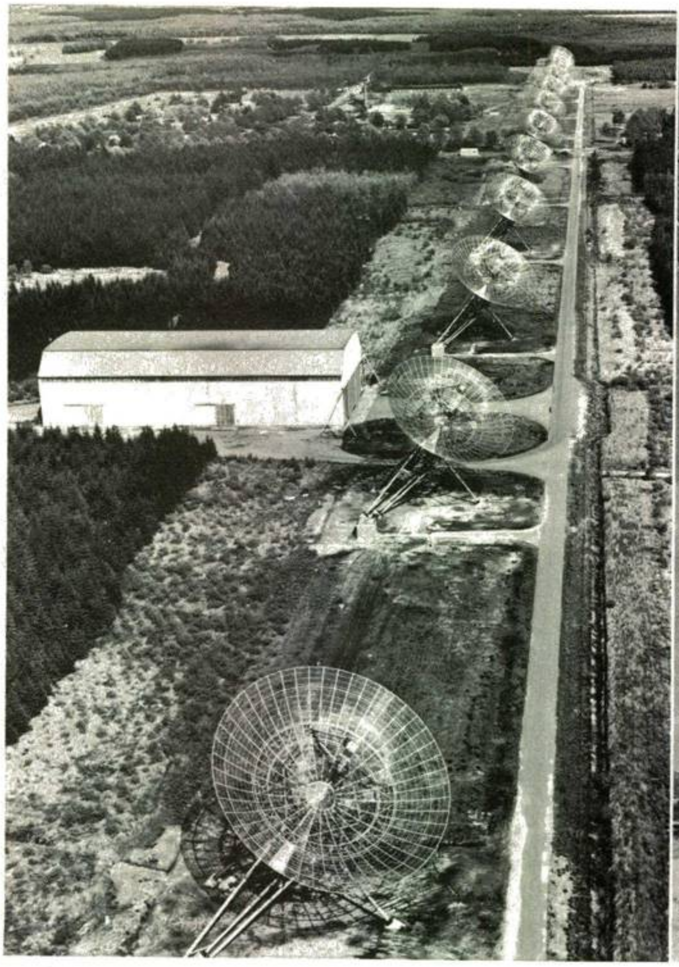
In some regions of the sky, where distant dust clouds obscure any light coming from beyond our galaxy, the radio telescope can measure radio waves passing freely through the dust. Radio photographs of at least two objects totally hidden behind this dust have identified them as galaxies located about six million light-years away.

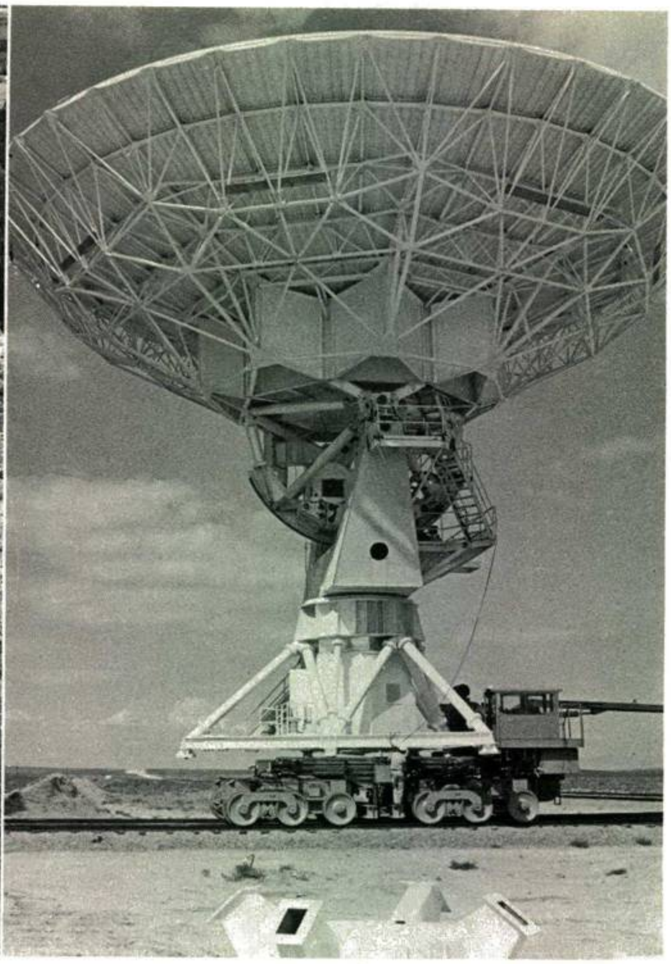
Radiographs have also revealed other phenomena invisible to the eye. Several very distant galaxies known to be strong emitters of radio signals have had radio prints taken by radio telescopes, and show long radio emission tails covering enormous volumes of visually dark space. Apparently these radio galaxies have ejected vast quantities of matter outward into regions where radio waves — but no light waves — are emitted. These tails stream out behind the parent galaxy.

Not all radio emitting galaxies show tails. Many radio galaxies appear to have ejected two clouds of material in opposing directions, which are capable of emitting strong radio signals for millions of years. Such double radio sources — some enormously large — are common. The largest, an object called 3C 236, is 1.6 billion light-years away; its radio emitting regions stretch over 16 million light-years. The radiograph of this source shows the emission coming from two "wings" far from the optical galaxy, once believed to have been the center of the expansion. There are still many problems in explaining the cause of such explosions and why they are able to eject so much energy so that the distant double source can still emit radio energy millions of years later (see page 8).

A recent sophisticated variation of the radiograph has been the production of a photo showing where cold hydrogen gas is located in a galaxy. The map of M-81 shows a beautiful spiral pattern for the hydrogen, similar to the galaxy's stellar pattern. However, the pattern degrades as one moves away from M-81's nucleus (see pages 6 and 7).

Radiographs are a fascinating new way to "see" objects in the universe. They provide the radio astronomer and layperson an idea of what celestial collections look like at nonvisual wavelengths. ◆





Left: The radio photographs in this article were made with an interferometer array consisting of 12 radio telescopes, with their signals combined mathematically to yield high resolution images of radio sources. Photograph courtesy of Westerbork Radio Observatory; copyright © Aerophoto Eelde. Right: Here we see one of the antennas of the Very Large Array, a powerful and versatile radio interferometer now under construction on the Plains of San Augustin, near Magdalena, N.M. Photograph by William Logan.

sought by many astrophysicists, the reason for this is not yet understood. High-resolution radio maps have further revealed that some of the radio galaxies known for many years are turning out to be surprisingly large. Recent observations made with the Westerbork aperture synthesis radio telescope in the Netherlands indicate that radio galaxy 3C 236 (located in the constellation Leo Minor) is 18 million light-years in diameter (approximately 200 times larger than the Milky Way), making it the largest known object in the universe. Also, the observations have provided the first direct proof that an exceedingly tenuous gas fills the space in clusters of galaxies, as revealed by detailed radio maps.

Many of the results obtained using aperture synthesis have baffled theoreticians, who are presently unable to fully explain the shapes and energy sources of the radio galaxies. However, puzzling observations such as these often pave the way for dramatic scientific advances.

Even more powerful radio interferometers will soon be in operation. The Very Large Array (VLA) presently under construction near Socorro, N.M., will be the largest and most sensitive radio telescope in the world. It will consist of 27 movable, dish shaped antennas; each will be 82 feet (25 meters) in diameter. Each 200 ton antenna, mounted on a platform, moves along standard gauge railroad tracks which make up three "arms" of the interferometer. Each arm is 13 miles (21 kilometers) in length. A short piece of spur track branches off from the main track of each arm at regular intervals to provide observing stations for the antenna. When necessary, each antenna can be wheeled from one observing station to a different observing station.

When the VLA is completed, it will provide radio astronomers with the most powerful instrument ever constructed for observing distant radio objects. Since each antenna can be pointed to any position in the sky, the entire array will closely duplicate the performance of a fully steerable radio dish, 17 miles (27km) in diameter.

Aperture synthesis will be used extensively by the VLA. The 17 mile phantom aperture will be filled in by a combination of two different motions. The first consists of hauling the antennas into new observing positions, and the second consists of simply letting the rotation of Earth change the positions of the antennas. Tremendous computer sophistication is needed to translate these observations into a radio picture, because the 27 antennas will produce 351 different interference patterns. Present day computer systems can handle the mammoth data processing requirement. The completed VLA will be capable of producing detailed radio pictures of an area of the sky smaller than the full moon, with resolution better than one second of arc.

The movable antennas of the VLA offer the additional advantage of enabling astronomers to choose whether resolution or sensitivity is more important in making a particular observation. When the antennas are spread out the greatest possible distance apart along the arms, the VLA will have very high resolution. But when they are clustered near the center, the resolving power will be lower and its sensitivity for detecting faint radio objects will be at its peak.

It seems unlikely that the recent dramatic advances in radio telescope performance will end with the VLA. Radio astronomers have already been experimenting with *intercontinental* interferometry. Radio telescopes many thousands of miles apart have, from time to time, been linked up to achieve resolutions of better than 1/1,000 second of arc. The technical difficulties to be overcome in intercontinental interferometry are enormous. Not only must telescope time and observing plans for several observatories in different countries be coordinated well in advance, but the phase of the waves being received at each telescope must be tape recorded so they can be combined later — a task requiring such extreme accuracy in timekeeping that atomic clocks must be used. Furthermore, the exact distance between the antennas of the interferometer must be known within a fraction of an inch. The sun and moon produce small tides in the solid Earth, which must be taken into account in such exacting work. Thus, even the changing shape of our planet becomes a factor to be considered in intercontinental interferometry.

A proposal for a full-time Very Long Baseline Interferometer (VLBI) has recently been made. Radio astronomers G.W. Swenson Jr. and K.I. Kellerman have shown how it would be possible to set up 8 to 10 antennas — similar to those being built for the VLA — to create an interferometer spanning several continents, which could be added to existing radio observatories. The VLBI would be capable of synthesizing the radio "pictures" that would be produced by a fully steerable radio dish *nearly the size of Earth.* After a careful study of the problem, the two scientists have concluded that it is both possible and practical to build a VLBI at the present time. The proposed instrument, which could produce radio "pictures" of quasars, pulsars and other puzzling objects with resolutions of up to 1/10,000 second of arc, would cost approximately $20 million — not a large sum of money in the context of present day expenditures for space research.

Recently radio astronomers in Maryland, California, Australia and the USSR have joined their telescopes together using the VLBI technique. The resolving power of this scope is that of the size of Earth, capable of resolving a source less than 2/10,000 second of arc — comparable to the thickness of a human hair at a distance of 100 miles (160km).

Having seen how it is possible using present day technology to synthesize a radio aperture approximately the size of Earth, there is no reason to stop there. It is entirely possible that large radio antennas may eventually be set up in space, to create a giant orbiting interferometer. To obtain even greater resolution, the antennas might be placed into orbit around the sun, scattered at various points along the circumference of Earth's orbit. An interferometer having a 186,000,000 mile baseline (the diameter of Earth's orbit) could achieve — at the 21cm wavelength — the astonishing resolution of better than 1/5,000,000 second of arc. Resolution such as this would allow a dramatic leap in our understanding of the nature and structure of radio objects, both within and beyond our galaxy. The technological problems to be overcome should not be underestimated. Present day technology is not capable of making the extraordinarily precise measurements necessary to operate an interferometer in space. But there is in principle no reason why an orbiting interferometer could not be built, and it seems entirely possible that the technology of the 21st century will no longer require that the resolution of its radio telescopes be limited by the size of our planet.

Ironically, radio astronomers, who only a few years ago were severely hampered by the inherently poor resolution of their instruments, have been so successful using interferometers that today their resolution surpasses the resolution of even the largest optical telescopes. Optical astronomers will gain higher resolution once the Space Telescope, long delayed by NASA's financial cutbacks, becomes operational in the early 1980s. However, radio astronomers will still be ahead because radio interferometry is much easier to put into practice than it is to build giant telescopes.

Because of the accelerating trend toward ever-increasing radio resolution, it is likely that the puzzling fundamental questions about the universe — raised by the energy production of quasars and radio galaxies — will be answered by observations made using powerful radio interferometers. Based on the exceedingly rapid pace with which radio interferometry has been progressing, it is reasonable to expect some answers by the end of the next decade.

Robert Sheaffer is a computer systems programmer/analyst for GTE Information Systems in the Washington, D.C. area. He is a graduate of Northwestern University, where he studied mathematics and astronomy.

Close-Up on Jupiter's Moons

by
Eric Burgess

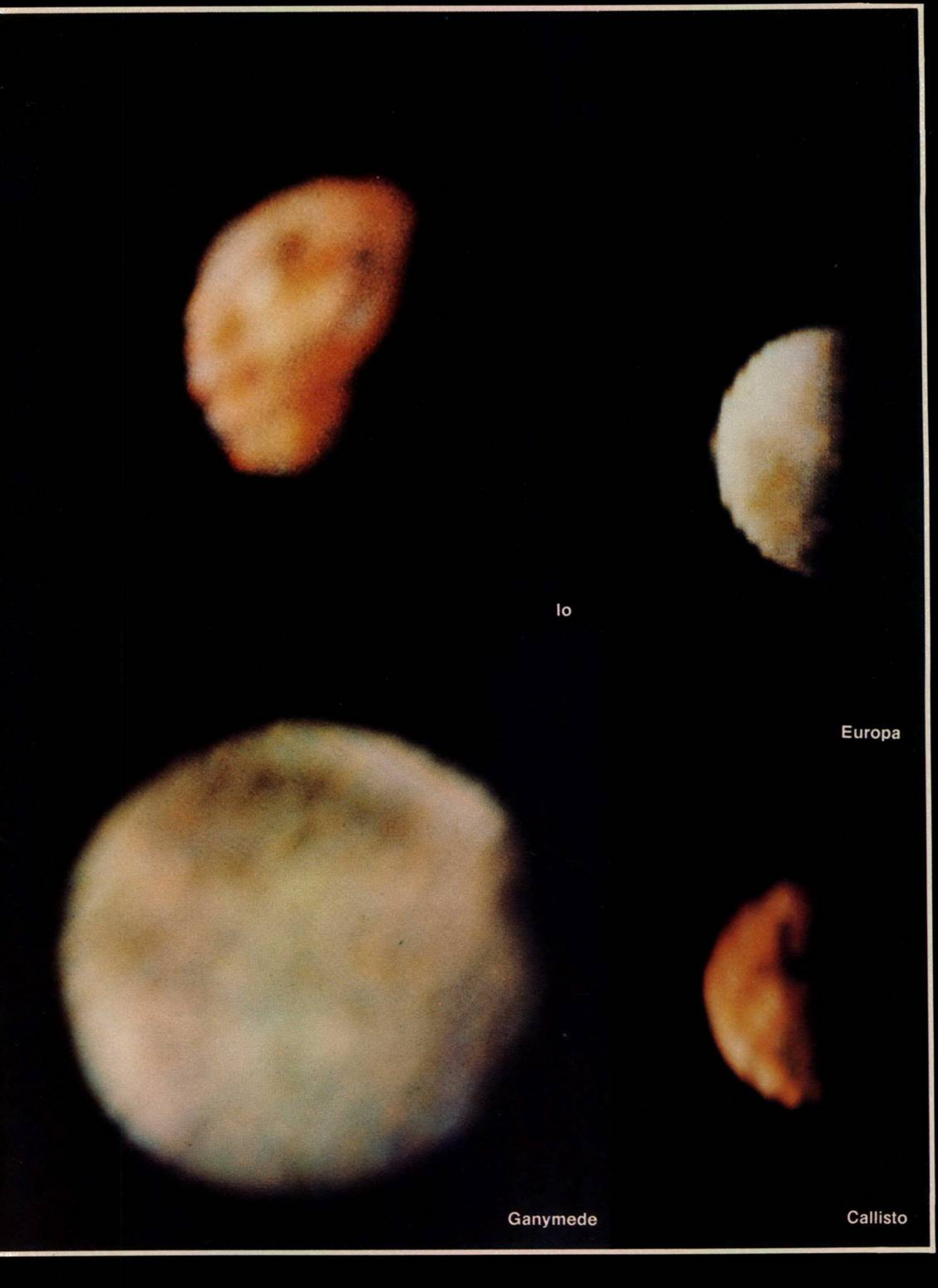
The photos on the following page — all from NASA — are the most recently processed images of the four Galilean satellites obtained by Pioneers 10 and 11. Although these are the best images currently available of the Galileans, the Pioneer spacecraft were located at a distance similar to that between Earth and our moon for the closest (Europa), and almost twice that distance for the others. Thus, only a small amount of detail can be seen.

The photograph of Io, showing its northern hemisphere, was taken from Pioneer 11 on Dec. 4, 1974, when the spacecraft was 470,000 miles from the satellite. The closest to Jupiter of the Galileans, Io is the most reflective object in the solar system — reflecting 60 percent of the sunlight falling on it. Its high albedo may be due to a surface coated with sulphates and salts of sodium and potassium. These salt flats may be the relics of ocean beds left behind when the primitive Jupiter boiled off Io's water. The surface of the satellite is probably cratered, which may account for the markings that show indistinctly in the photo. Io is the densest of Jupiter's large satellites — 3.5 times that of water.

Europa was photographed by Pioneer 10 on Dec. 4, 1973 from a distance of 200,000 miles. In the accompanying photograph , Europa's equator is slightly above center in this picture. Rocky like Io and comparable in size to Earth's moon, Europa has a density 3.28 times that of water. While the satellite is not thought to possess large quantities of free water, Earth based measurements reveal the presence of water ice. It is speculated that dark areas, such as those seen in the northern hemisphere on the photo, may be the sites of large impacts where an outer ice crust may have shattered to spread rocky materials on the surface. However, if the satellite differentiated after its formation through radioactive heating, it may not possess maria and craters such as those on Earth's moon; they may have been obliterated by subsequent evolution. Close-up photos to be obtained by the upcoming Mariner mission to Jupiter and Saturn may solve the question of whether or not the Galileans show evidence of the bombardment that molded the inner planets.

Pioneer 11 took this picture of Ganymede on Dec. 3, 1974 at a distance of 460,000 miles. Larger than Mercury, Ganymede is believed to consist of a silicate core surrounded by a deep, warm water ocean that is topped with thick glaciers. Spectroscopic observations from Earth indicate that Ganymede has large areas of water frost on its surface, though not as extensive as those on Europa. Radar observations suggest that the surface may consist of large rocks mixed with ice, possibly embedded beneath a smooth ice surface. The satellite's composition could account for its low density — only 1.95 times that of water. The photo shows many surface details; some have been likened to lunar maria, while others could be high plateaus. Ganymede is large enough to hold an atmosphere, possibly consisting of methane and ammonia. Io has an atmosphere and an ionosphere, but atmospheres have not been definitely identified on the other satellites.

The outermost of the Galileans, Callisto is shown here in a view that includes its south pole. Taken Dec. 4, 1974 by Pioneer 11 at a distance of 490,000 miles, the picture shows a prominent light region near the limb and darker areas that look remarkably like maria. But Callisto's density is only 1.62 times that of water, and it is a mystery how impact basins could remain on a satellite that probably consists largely of water and ice. It may have a very small silicate core, but Callisto may essentially be no more than a large drop of muddy water topped with an ice crust.


Io
Europa
Ganymede
Callisto

SEARCHING FOR MARS ON EARTH

by
William K. Hartmann

Mars is an unimaginably foreign place, but should it be strange? Compared to the range of conditions that exist in our solar system — not to mention possible systems near other stars — Mars is almost our next door neighbor, made of similar materials and only a little farther from the sun. Isn't it possible to find landscapes on Earth that can help us understand Viking's surface pictures of Mars?

Scientists are divided in an interesting way on this point. At one extreme, some assume other planets and satellites are so different that *no* terrestrial experience is useful in interpreting their surface properties. They reject similarities to terrestrial features, interpreting planetary surfaces from basic laws of physics. But many such interpretations have been wrong — for example, the theory that lunar maria are not lava plains (like the plains with similar features on Earth), but vast seas of superfluid dust moved by electrostatic processes, threatening incoming spacecraft with premature burial.

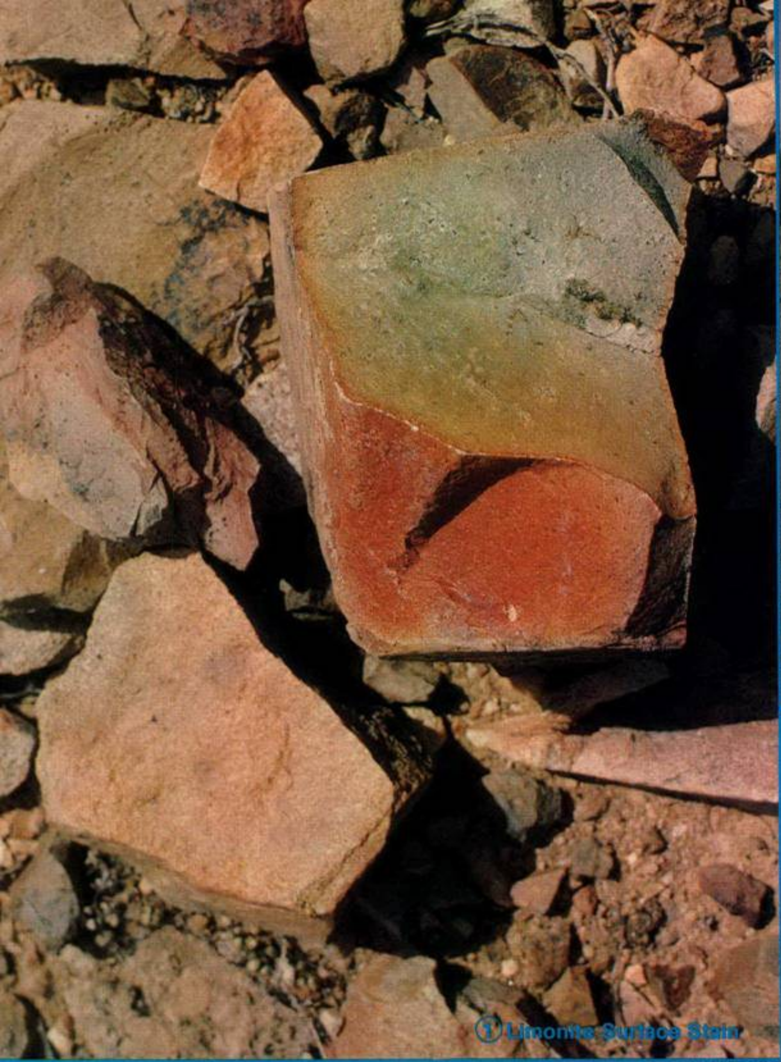
The other philosophic extreme is reasoning by analogy and experience, and it's probably fair to say that this method has been more successful in interpreting planets. For example, some pre-Apollo scientists noted that lunar maria contained lobate flow features, channels and other features similar to terrestrial lava flows. They reasoned that maria are lava flows, and as far as we can tell now, they were right. Of course, seeking terrestrial analogies is not foolproof; the problem of crater origins has not been fully resolved because scientists found lunar craters with similarities to both meteorite craters and volcanic calderas. (Most scientists today would say that large craters on the moon and planets are meteoritic, but some of the small craters are volcanic.)

Ideally, scientists should use both methods, but since reasoning by terrestrial analogy can claim some success in explaining features of the moon, it is intriguing to apply it to Mars. Since Mars is more Earthlike than the moon, the method should be especially applicable.

To find a Martian landscape on Earth, where do you look? A cold place? A high place? A dry place? How does Mars differ from Earth? If we have to pick one factor, what is most basic?

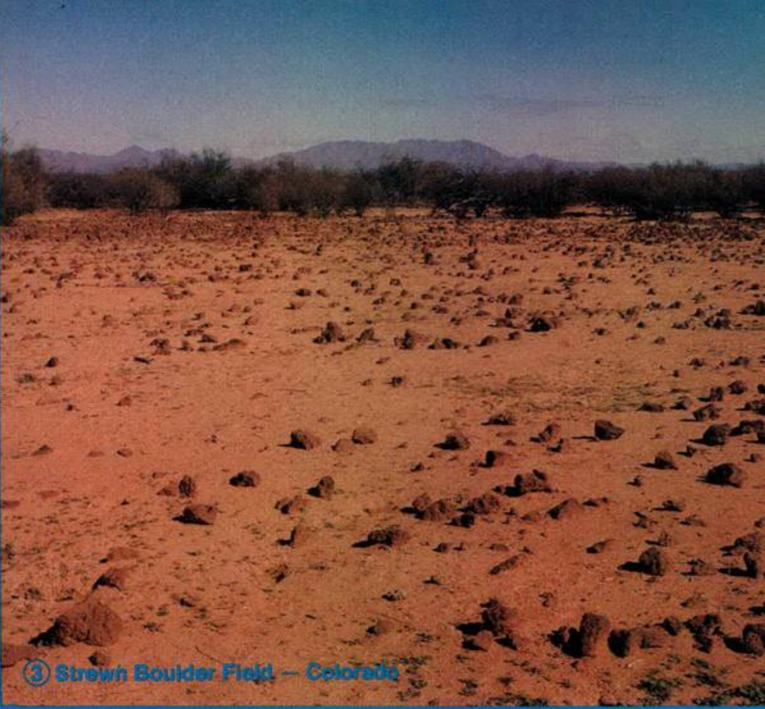
It turns out to be temperature, but this doesn't mean that we should look for a cold place to simulate Mars. Our cold places are at the poles, and are full of ice. Martian landscapes generally are not full of ice. So the most important real difference is a consequence of temperature: dryness. Earth is so warm that much of our water is liquid or gaseous, while Mars is so cold that virtually all the water is

Red is a common result of chemical weathering processes. Picture 1 shows a cracked rock with a limonite stain on the surface, but the fracture reveals an interior color of light gray. Rocks of varied original color may become stained "Mars red" by chemical weathering processes. 2) As with the rocks on Mars, terrestrial rocks show varying degrees of red and brownish color due to differences in the original rock type and the kind of chemical weathering it has undergone. 3) Orangish sediments, formed from a thin cover of lava, blow away leaving a covering of rocks. If enough dust is removed, the rocks will form a desert pavement preventing further erosion. This area — minus the plants — may resemble some areas on Mars. 4) Thin veneers of dust mask lava flow near the Amboy Crater in California. The dust, blown in from other areas, "paints" the dark basaltic lava surface its own color. 5) On a hillside near Arequipa, Peru, gray sand and Mars-orange rocks show the various patterns of color that can occur in arid regions. Photographs by William K. Hartmann.



① Limonite Surface Stain

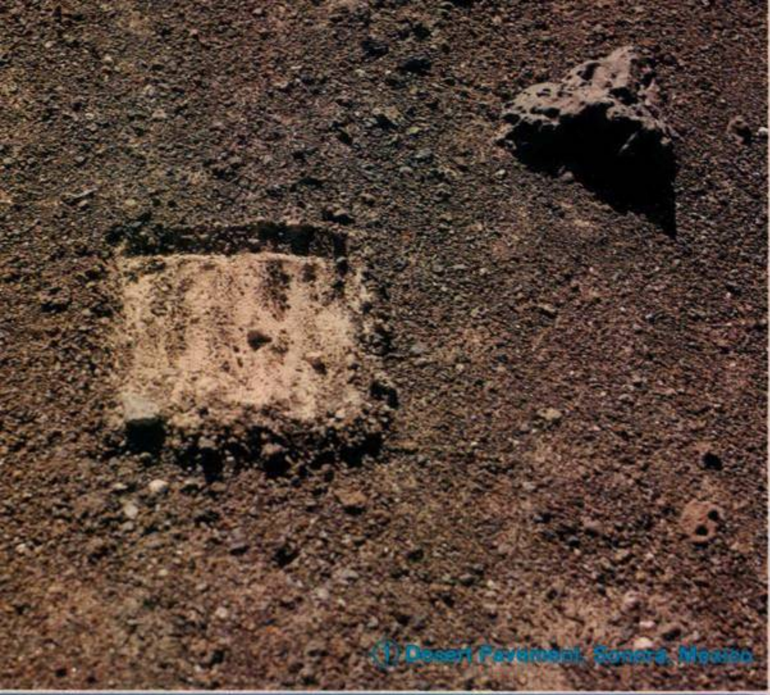
② Chemical Weathering — Arizona

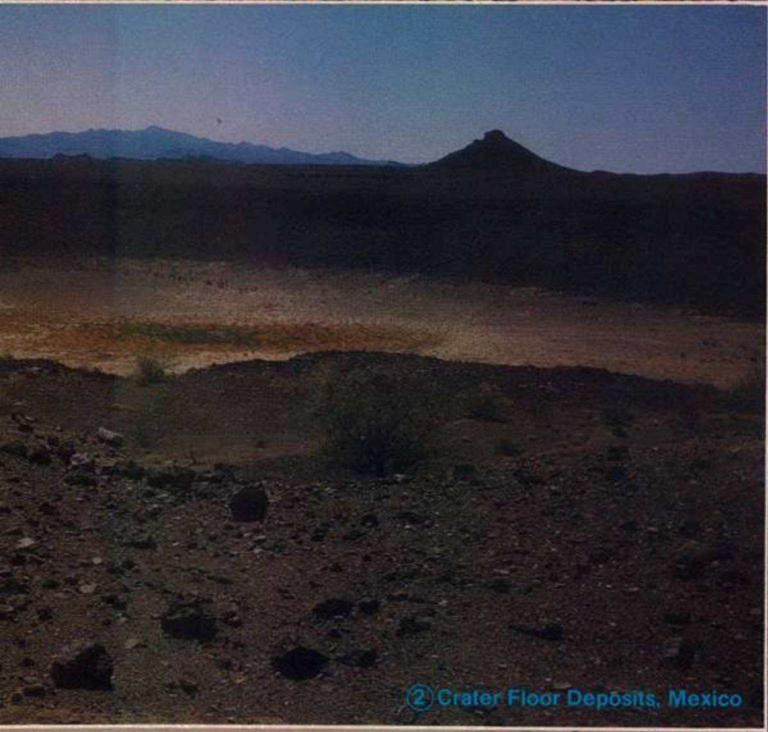


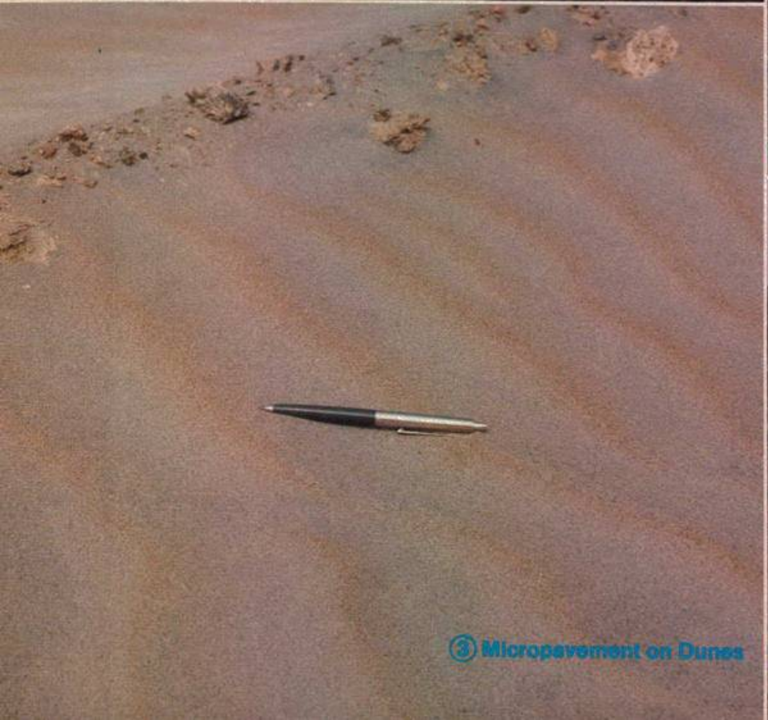
③ Strewn Boulder Field — Colorado

④ Amboy Crater, California

⑤ Orange Rocks and Gray Sand, Peru


① Desert Pavement, Sonora, Mexico


② Crater Floor Deposits, Mexico

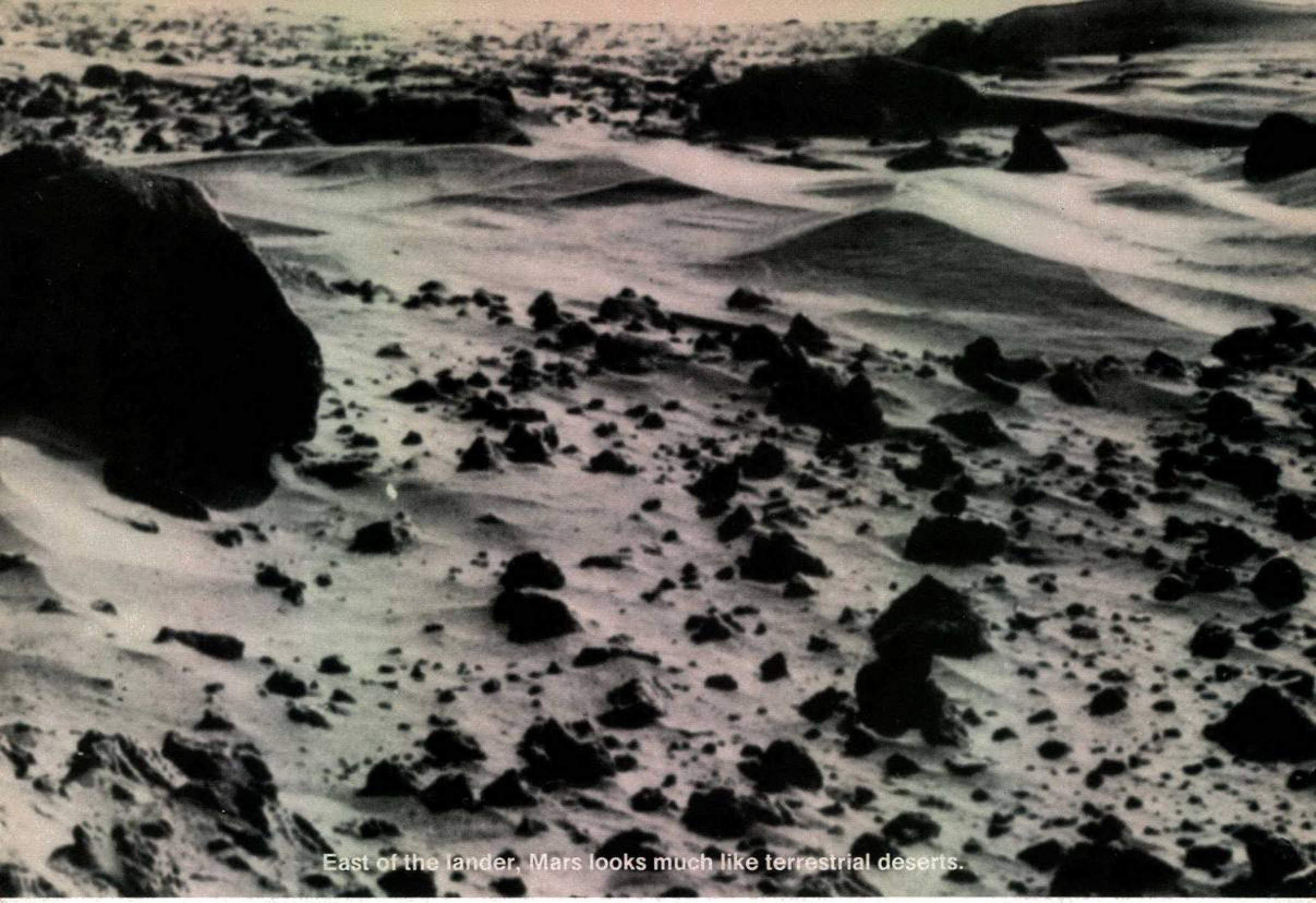

③ Micropavement on Dunes

④ Camana, Peru

⑤ Nasca, Peru

⑥ Sand and Haze in Peruvian Desert

⑦ Arequipa, Peru



East of the lander, Mars looks much like terrestrial deserts.

frozen solid and "locked away" as ice. So Mars is incredibly dry under current conditions. Thus, in order to find Marslike landscapes on Earth, look in dry places.

If you took a sequence of space photographs of Earth and arranged them in order of local aridity, you'd produce a continuum of landscapes ranging from moist jungles through dry sparsely vegetated regions, to desolate, barren deserts. Aerial views of Mars are not much different than the dry end of this scale; instead, pictures of Mars could be placed in sequence just a little bit beyond the driest regions on Earth.

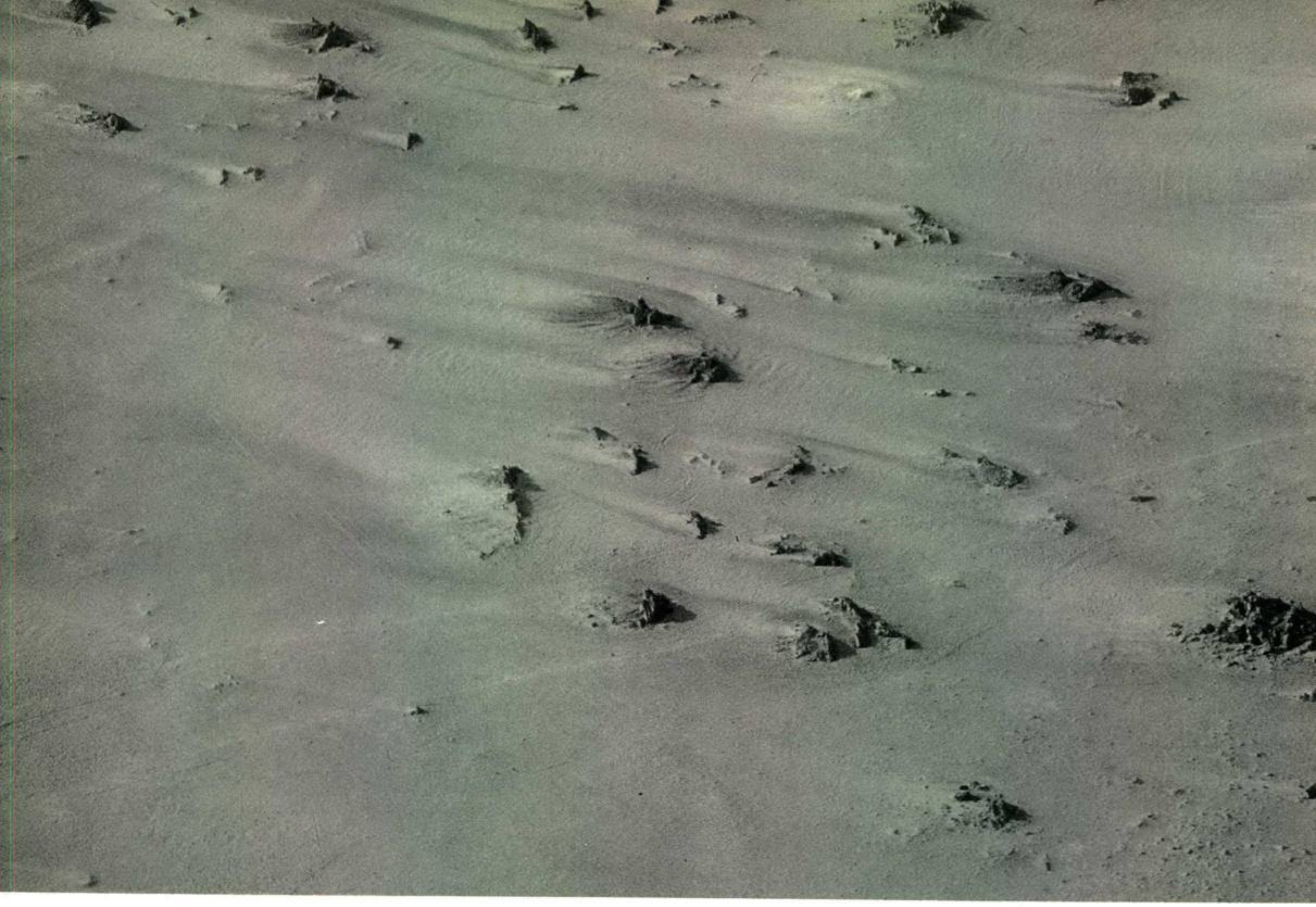
Red Coloration

Color is a good clue. Dark green forests are moist regions; brown soil and dotted plants are in the intermediate regions, and the vista becomes increasingly reddish-orange as you look to drier and drier regions. Mars (as is well-known) has orange and brick red landscapes. Although the rule is not ironclad, the general trend is that dry regions on Earth provide a geochemical environment where iron minerals are oxidized to rustlike forms of iron.

In terms of the shapes of geologic structures, the same kind of sequence applies. In moist regions, broad rivers cut through the topography, and mountain forms are rounded or dissected by waterflow processes. At the dry end of the sequence, however, rivers evaporate, and there are few plants to retard wind erosion. In the driest parts of Earth, wind is the major erosive agent —a fact that is apparently making a growing impression on geologists.

Thus, the place to find Mars landscapes on Earth is dry regions, where chemical processes produce reddish iron-oxide minerals, and where winds will blow dry dust to create landforms like those on Mars.

1) In the Pinacate lava fields of Sonora, Mexico, dark volcanic gravel protects the fine yellow underlying dust from wind erosion. The gravel is pushed aside in a two inch square to reveal the dust; similar pavements on Mars could explain the dark markings in light desert regions. 2) This volcanic crater shows yellow dust deposits on its floor, left when wind- and water-borne sediment could not escape. 3) This close-up of a sand dune shows how wind sorts granular material. Orange dust rests on the crests of ripples, while larger gray grains have accumulated in the troughs. On a larger scale, material can be sorted for size and color. 4,5,6,7) Marslike scenes in southern Peru show white evaporation deposits (4), scattered rocks and windblown sand (5), featureless desert vistas (6), and a now-dry stream valley similar in shape and dimension to some channels on Mars; hills show a similar profile with piles of talus on the bottom (7). While visiting Peru, the author wrote: "Enormous gray and tan sandy wastes, leading under leaden skies to the distant, misty Andes foothills . . . surface is a smooth sandy waste, sometimes with one meter dunes, but no desert pavement and very few rocks . . . colors appear in streaky windblown patches . . . hundreds of miles of barren brown rolling desert . . . vistas as far as the eye can see disclose no plants at all in any direction. I think I have now seen Mars . . . ." Photographs by William K. Hartmann.

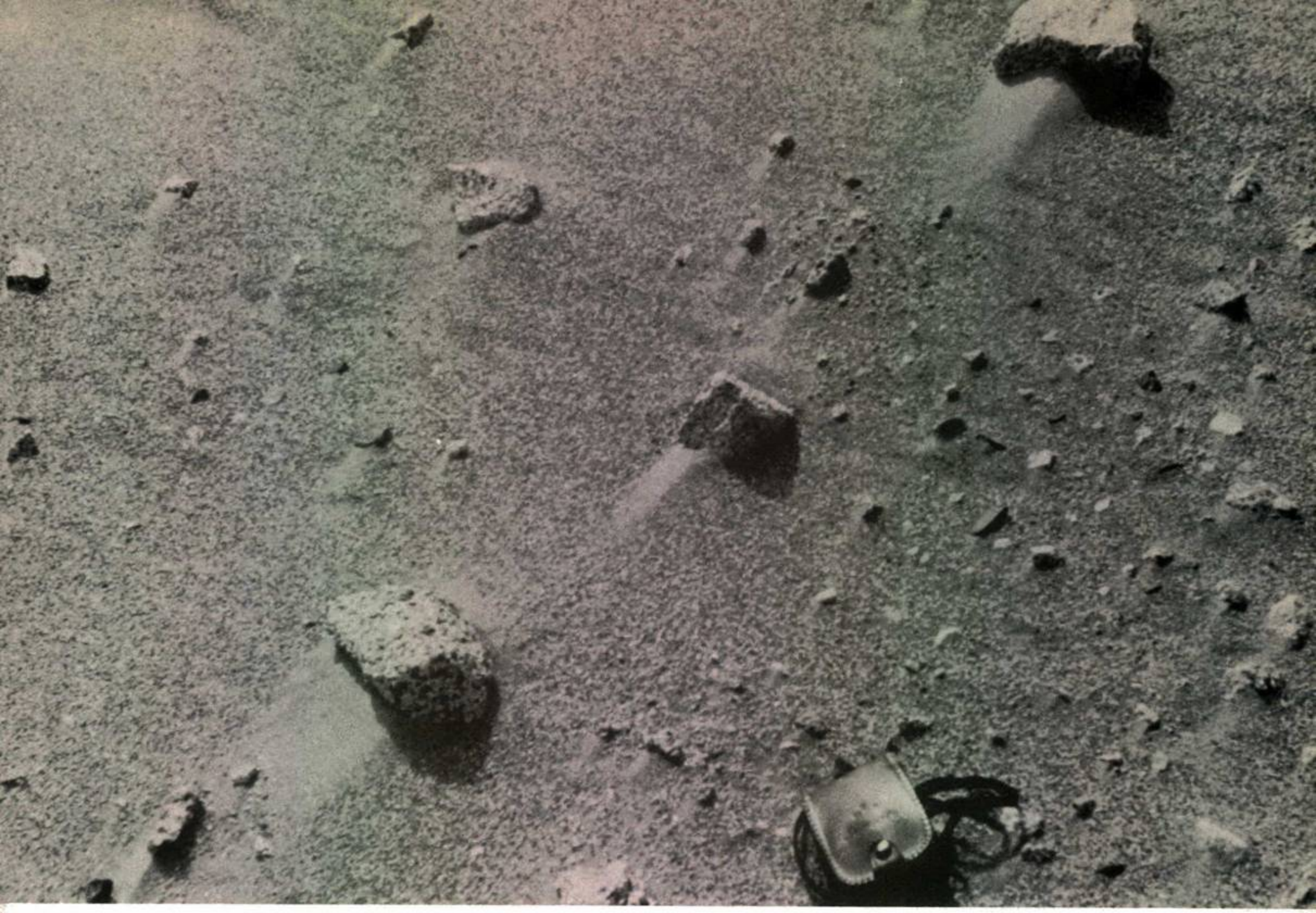


In very arid areas with prevailing winds, such as this region south of Lima, Peru, obstacles such as bushes or rocks change local wind patterns and cause deposition or removal of dust in long "wind tails" on the downwind side. Identical wind tails extend from some craters in the windy regions of Mars. Photograph by William K. Hartmann.

Within the United States, the first choice is the southwest, where reddish-orange deserts were long ago studied as Martian analogs. In the early 1960s, when Viking scientists Alan Binder and his colleague Dale Cruikshank were studying at the University of Arizona, they examined reddish rock units in southern Arizona and compared them with Mars. They found Mars spectra resembled spectra of rocks that had acquired a surface stain of oxidized iron minerals of rustlike color! The closest match to Mars appeared to be a material called *limonite*, a mixture of several oxidized, hydrated iron minerals such as hematite (Fe_2O_3) and goethite ($HFeO_2$). Other workers found additional, similar, oxidized iron mineral combinations that matched Mars. In arid southwestern deserts (with annual rainfalls of 15-30 inches), limonite stains could color volcanic rocks orange in only a few years. They speculated that Mars' orange color might have originated in the past during a period that was arid, but more humid than it is today. With Mariners' and Viking's subsequent discovery that rivers ran on Mars in the past, this does not seem unlikely.

Thus, when MIT researcher Robert Huguenin later showed that iron minerals could oxidize on Mars by exposure to solar ultraviolet light, Mars was doubly favored for rust-red minerals. In any case, Binder and Cruikshank predicted the following picture of Mars in 1966: "The Martian bright areas may be composed of rock outcrops, detritus with particles ranging in size from large fragments to sand size grains, and some limonite dust. The outcrops and detrital fragments are, for the most part, covered with a hard surface stain of the type of limonite that is formed and preserved in a desert environment."

Judging from the Viking pictures, this appears to be close to the truth. There are rock outcrops, fragmented rocks, and a large amount of reddish dust that is probably an oxidized iron mineral — perhaps limonite. Not all the rocks are covered with a uniform stain, however, since the pictures show some dark gray rocks, some brown rocks, and other rocks of slightly different red tones. Viking photos show that darker soil is under the red surface dust of Mars, suggesting that only a part of the total Martian soil has been completely oxidized to red color. It also supports the theory that changing and contrasting bright Martian deserts and dark patterns are created by thin, shifting variegated dust blown by the wind and deposited on backgrounds of various tones.



Wind tails similar to those in the first pictures from Mars appear on the cold arid sand of the Victoria Valley in Antarctica. Prevailing winds have carried fine material in the downwind "shadows" of the rocks. A photographer's light meter, about four inches (10cm) long, appears in foreground. Photograph courtesy of T. Mutch and R. Stockman.

On Earth, paleogeologists have long recognized vast strata of red colored deposits, often called *red beds*. Geologists used to think these were simply deposits derived from erosion of red rocks or red soils. However, in 1973, Princeton geologist F.B. Van Houten reviewed a decade's work on the subject and showed that terrestrial red deposits usually begin as brownish soils that change to reddish color by oxidation of iron minerals, especially in desert climates, and especially when moisture amounts fluctuate. Interestingly, it may mean that Mars — with its hypothesized episodes of water activity interspersed with long arid periods and ultraviolet light — is the ideal place in the solar system to form red soil!

Windy Landscape

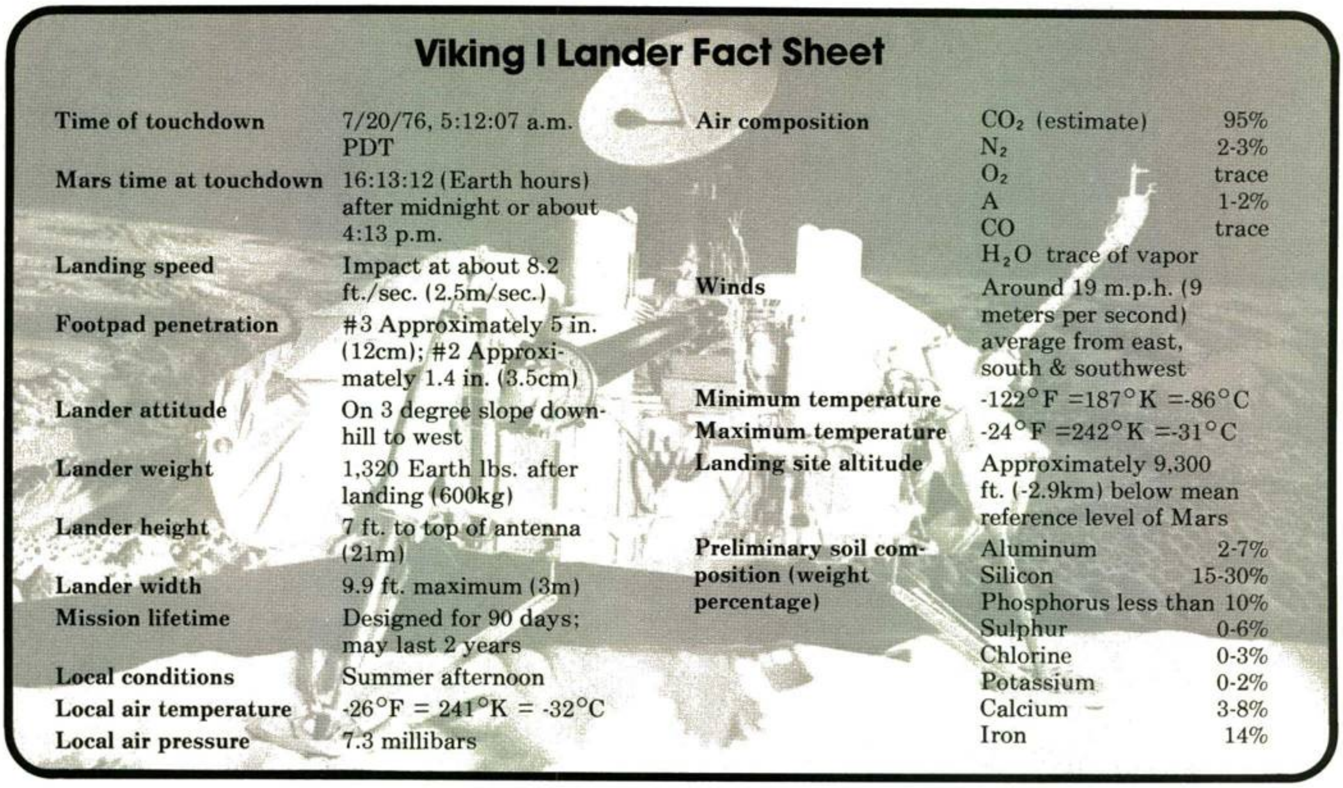
As for landforms and the appearance of Martian rocks, we need to examine on Earth what the wind — and infrequent water flow — do to the landscape. In parts of the Sonoran coastal deserts of northwestern Mexico where rainfall amounts to only a few inches per year and there is less vegetation to hold down the dust, a probable Martian process is seen where windblown orange dust is blown in thin veneers across lava flows. The structure of the flow can still be seen from the air, but the color is not the gray-brown of the lava but the orange of the dust. Orbiter pictures of the Tharsis Volcano reveal lava flows that have run out from the volcano, but most flows seem to be orange like Martian dust. Similarly, the reddest colors at Viking 1's Chryse landing site seem to be a thin layer of dust over browner rocks and soil.

In some areas, an accumulation of rocks and pebbles on the surface (called *desert pavement*) forms as wind winnows away the dust, until the soil is protected from further erosion by a covering of remaining rocks. The rocks may have a different coloration than the soil; they may, for example, be darker and browner than the limonite powder. This may be an explanation of many of the dark, brownish regions that compose the classical markings of Mars.

Martian Dunes

Before World War II, English scientist R.A. Bagnold became interested in the little-studied subject of dunes. After years of study, in 1941 he published a summary of his work which was virtually ignored. In the Middle East during World War II, he extended his observations of the factors governing size and shape of dunes, effects of wind speed, etc., but noted that more data were needed to under-

Viking I Lander Fact Sheet



Time of touchdown	7/20/76, 5:12:07 a.m. PDT
Mars time at touchdown	16:13:12 (Earth hours) after midnight or about 4:13 p.m.
Landing speed	Impact at about 8.2 ft./sec. (2.5m/sec.)
Footpad penetration	#3 Approximately 5 in. (12cm); #2 Approximately 1.4 in. (3.5cm)
Lander attitude	On 3 degree slope downhill to west
Lander weight	1,320 Earth lbs. after landing (600kg)
Lander height	7 ft. to top of antenna (21m)
Lander width	9.9 ft. maximum (3m)
Mission lifetime	Designed for 90 days; may last 2 years
Local conditions	Summer afternoon
Local air temperature	-26°F = 241°K = -32°C
Local air pressure	7.3 millibars

Air composition	CO_2 (estimate)	95%
	N_2	2-3%
	O_2	trace
	A	1-2%
	CO	trace
	H_2O trace of vapor	
Winds	Around 19 m.p.h. (9 meters per second) average from east, south & southwest	
Minimum temperature	-122°F =187°K =-86°C	
Maximum temperature	-24°F =242°K =-31°C	
Landing site altitude	Approximately 9,300 ft. (-2.9km) below mean reference level of Mars	
Preliminary soil composition (weight percentage)	Aluminum	2-7%
	Silicon	15-30%
	Phosphorus less than	10%
	Sulphur	0-6%
	Chlorine	0-3%
	Potassium	0-2%
	Calcium	3-8%
	Iron	14%

stand the growth and movements of dunes.

When Mariner 9 discovered beautiful dune fields on Mars in 1971-72, Mariner scientists rushed to the library to check the literature on the formation, size and spacing of dunes. The "literature" turned out to be, basically, Bagnold's book. Some physics of dunes, such as how fast the wind must be blowing to pick up sand particles of various sizes, and how shapes and spacing of dunes depend on local conditions, were explained — but no one had thought much about how these numbers would change in the Martian environment.

Therefore, Viking scientist Carl Sagan contacted Bagnold, and in 1975 they jointly produced a new study showing that in the thin air of Mars, winds of several miles per hour might begin to stir microscopic dust grains. Ronald Greeley and his colleagues at NASA's Ames Research Center have simulated Martian conditions in wind tunnels, showing how erosion as well as dunelike deposits can start downwind from rocks, hills and crater rims. On Mars (as well as in the lab), long streaks called "wind tails" extend downwind from rocks, craters, and other obstacles. Thus dune regions of Earth are closely related in appearance and physics to the dunes of Mars.

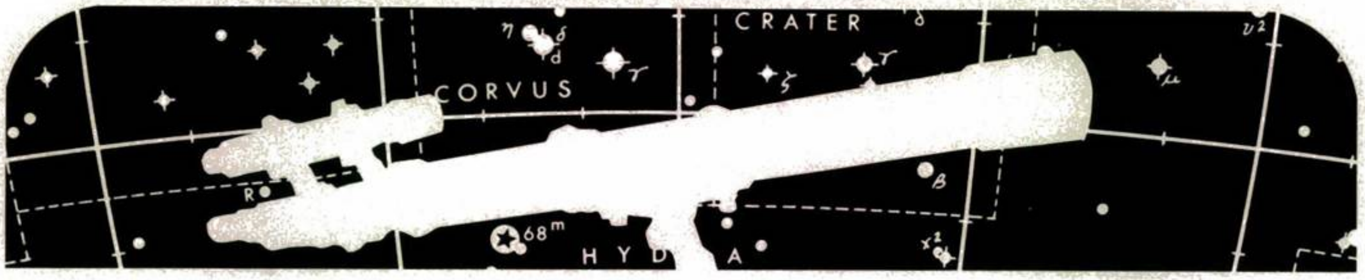
Another effect of dunes and sand deposits is to separate materials of different color and brightness. Various minerals fracture differently, have different aerodynamics, and are moved differently by the wind. This may be another factor in the ability of Mars' rocks and windblown dust to form patchy markings of different brightness.

Wind Sculpturing

Another effect observed on Earth is sculpture of rocks by the sandblasting effects of wind. As wind drives particles, they bounce and sail a foot or two above the ground, pitting rocks that are in their paths. If the winds come from one prevailing direction, the sandblasting occurs on one side. But if the wind comes from two prevailing directions, or the rock is flipped over by a gust, it can be sculpted into a faceted appearance with sharp edges. Rocks with mixed strong and weak minerals may be cut in peculiar ways as weak materials are cut away. Viking scientists are studying Martian rock shapes to look for evidence of such processes.

Some of the best candidates for Martian landscapes are in the arid coastal deserts of Peru. Here, there has been so little rainfall that prehistoric textiles from 1,000 years ago can be found unrotted, protruding from the sand, as if they were lost by a camper last week. As on parts of Mars, dust deposits have blown in and partially covered rocky soils, sometimes piling up as dunes.

From a subjective viewpoint, the most awesome aspect of the Peruvian desert is to look as far as you can and observe absolutely no form of life. But the upshot of the search for Mars on Earth is, perhaps, the finding that Mars is not so incredibly different from places on our own planet. The idea of man someday going there seems less and less farfetched. Of course you would need a space suit, but as Viking has shown, nitrogen and oxygen should be obtainable to make a breathable atmosphere. With a heater, we can imagine a future manned research station. Outside it, a future person may stand and scoop up a handful of red Martian soil, look around and say: "Yes, this place is not so foreign; Mars is only a small step beyond Earth."



Star-Test Your Telescope

by
Richard Berry

If your telescope does not deliver top performance, it may be that it's not defective, but only somewhat out-of-whack or misadjusted. Tricky optical testing methods can be used to bring it into the best possible adjustment, but they're usually beyond the time or price that most observers can afford. The best testing method doesn't cost a thing and takes just a few minutes on any evening: You can test your telescope on the stars!

The first thing you'll need to know is how the image formed by a "perfect" telescope looks. A star doesn't appear as a tiny, perfect point of light in any telescope because of the wave nature of light. As the beam of light comes through the telescope optics and approaches the focus, the converging waves interfere, producing diffraction phenomena — the most familiar one being the *Airy disk.* At the focus of a perfect optical system, about 84 percent of the starlight falls into this central disk; the remaining 16 percent falls into a series of *diffraction rings* surrounding the Airy disk. There is no way to eliminate the spurious disk and rings; they are caused by the very nature of light, and not by the telescope. If your scope is not performing correctly, however, you won't see the ideal diffraction image, but variations on it. Depending on what you see, you can figure out what the problem is and correct it.

The most common departures from a "perfect" optical system are unavoidable, and occur with the secondary mirror and spider legs in Newtonians, the secondary mirror in Schmidt-Cassegrains, and the secondary spectrum of chromatic aberration in refractors. The secondary mirror causes the Airy disk to be dimmer and the diffraction rings to be brighter; thus, with Newtonians and Schmidt-Cassegrains, you'll see more and brighter diffraction rings than you will with an unobstructed refractor.

Newtonian spider legs (which hold the diagonal mirror) cause spikelike rays to protrude from the star's image. With one-legged diagonal support, you'll see two spikes; with a three-legged support you'll get six spikes, and four spikes will appear with a four-legged support. The thinner the spider legs are, the dimmer the spikes will be.

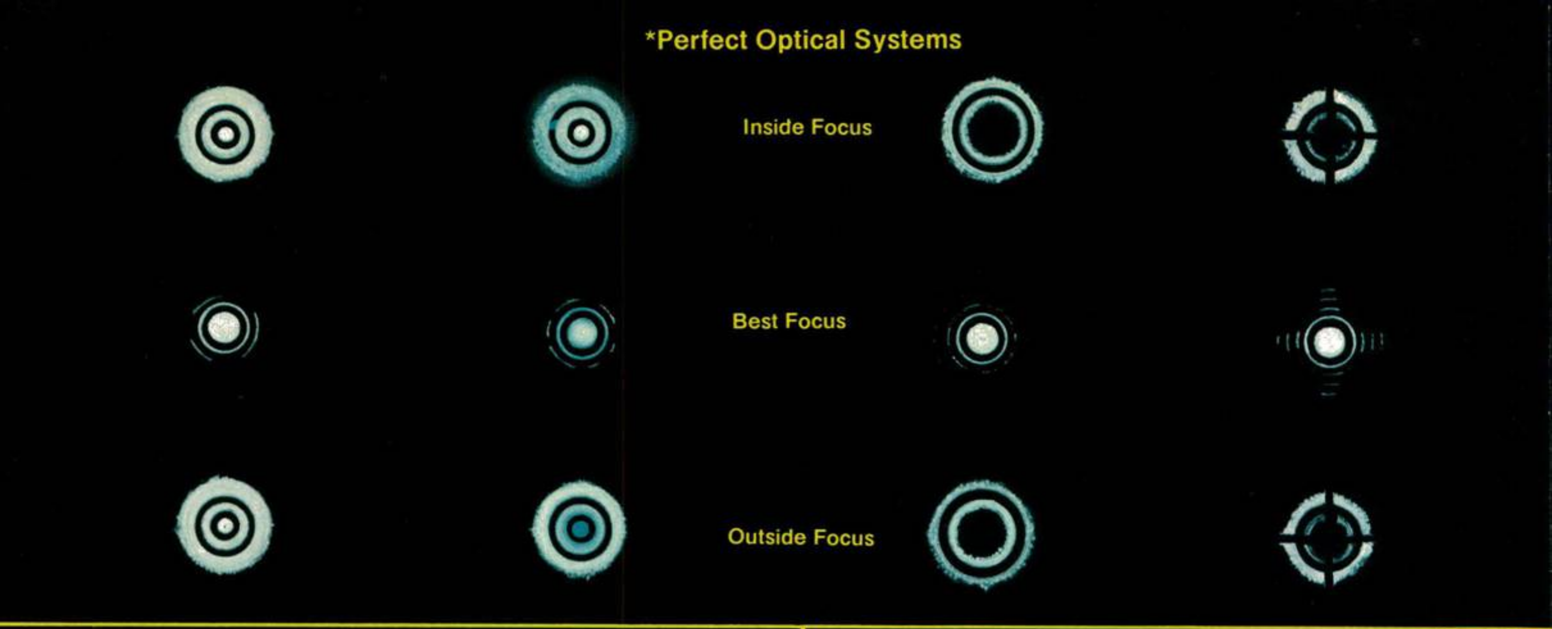
Even the very best refractors cannot bring light of all colors into perfect focus. Usually, blue light departs from focus the most, so if you examine a refractor's image carefully you'll see an out-of-focus halo of blue light surrounding bright star images. With faint stars, the halo is too dim to see and does not matter.

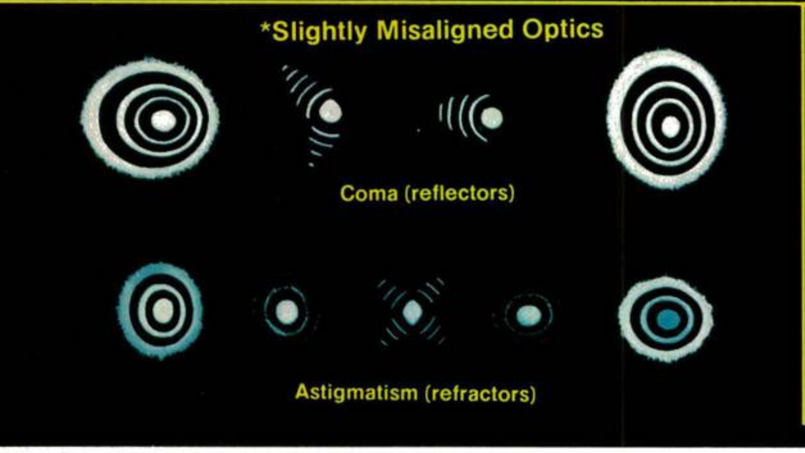
How To Test

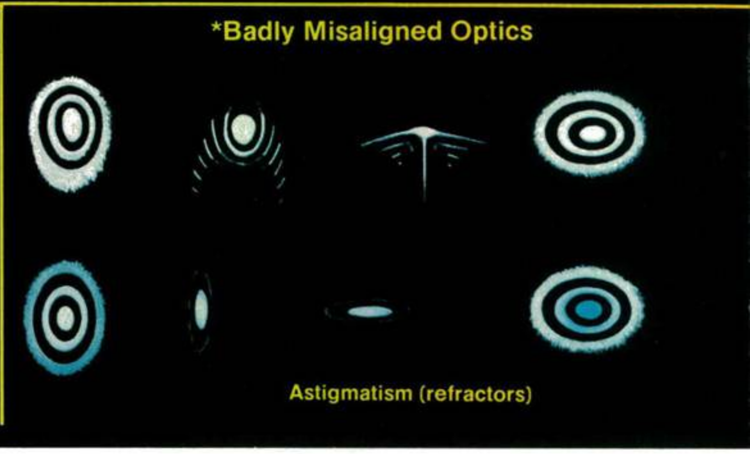
Once you know how a star image *should* look, you are ready to star-test your telescope. On nearly any night when the seeing is good, set-up as you normally would for observing; then point the telescope at any fairly bright star. Usually first magnitude stars are best since they aren't so bright; you'll get glare, but the stars are bright enough to let you see delicate details of the diffraction rings.

To see the Airy disk well — and it is very small — use a power of over 40 for each inch of telescope aperture. Thus for a three inch refractor, 150 to 200 power would be good; for a six inch reflector, 250 to 350 would be best. If the atmosphere is stable when you focus on the star, you won't have any trouble seeing the image produced by the telescope. But if the atmosphere is unstable, producing a "boiling" or shimmering image, you won't be able to test the telescope because all you'll see are atmospheric effects.

In addition to looking at the image *in* focus, you'll find that observing it *out* of focus is valuable in gauging your telescope's performance. Assuming


*Perfect Optical Systems


*Slightly Misaligned Optics


*Badly Misaligned Optics

for a moment that the telescope is reasonably good, what will you see when you focus? Start a long way outside focus — enough so that the star image fills perhaps 1/4 the eyepiece field of view — and you'll see a big disk, along with whatever secondary mirrors and spider legs obstruct aperture. Notice that a pattern of rings and fringes runs around the edge of the mirror and all the obstructions. Now focus the eyepiece slowly; the entire disk will become smaller. When it's small enough, you'll notice that the rings extend all the way to the center of the image. As you focus, the innermost rings disappear and the other rings move toward the center. When only two or three rings are left, the pattern is very sensitive to some types of telescope faults. Therefore, our illustrations show the "three ring" stage of focusing for most of the faults. As the image comes to focus, you'll see the Airy disk and diffraction rings; then as you go inside focus, you'll see the *exact reverse sequence* of ringed patterns form. If the appearance is not exactly the same on both sides of focus, or if it is not perfectly symmetrical, your telescope is not optically perfect.

Misalignment

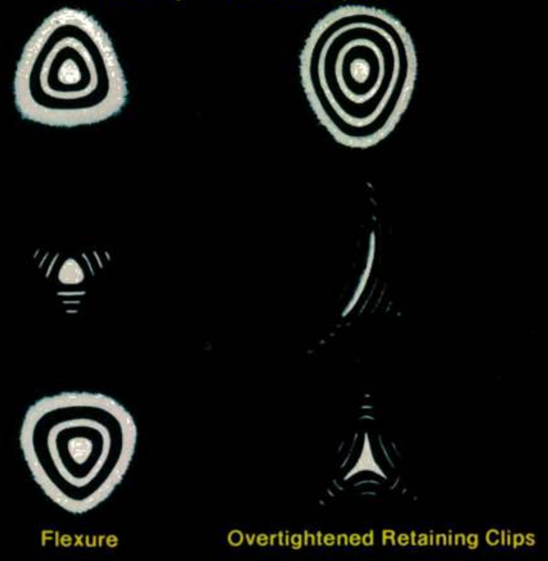
The most common cause of less-than-perfect performance is misalignment — where the main mirror, the secondary mirror in Cassegrains, or the lens in refractors is tipped out of line with the telescope tube. Misalignment produces a problem called *coma* in reflectors; the star is not symmetrical when focused, but has an extension off to one side. The comatic image also looks distinctive when out of focus. The drawings on page 28 show the complete sequence of images produced through focus by the "average" misaligned mirror, a badly misaligned mirror, and a slightly misaligned mirror. To eliminate coma, turn the adjustment screws on the main mirror of a Newtonian, or the secondary of a Schmidt-Cassegrain, in the direction that causes the star image to move *toward* the comatic extension of the image. This is best accomplished with one person to turn the screws and another to watch the star image. If you're careful, however, you can do it yourself.

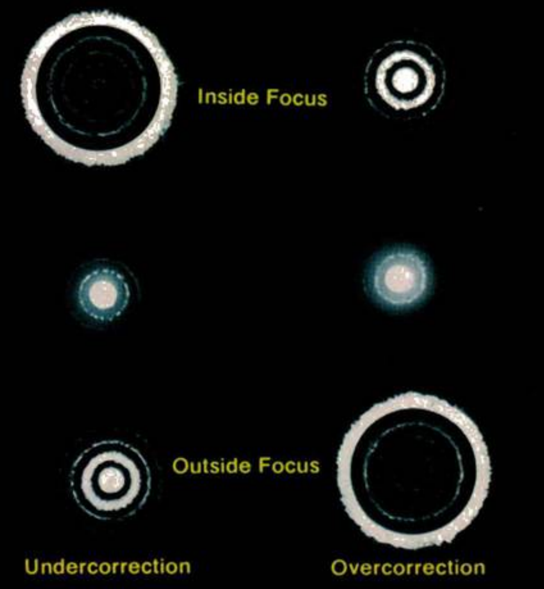
If your refractor is out of alignment, the result is not usually coma, but *astigmatism*. Astigmatism looks different than coma: The star focuses to a short line, then a cross, then another short line at right angles to the first. The image is oval when out of focus. Most good quality refractors have adjusting screws so that the lens cell can be tilted into perfect alignment — and once correctly aligned, they almost never get out of alignment.

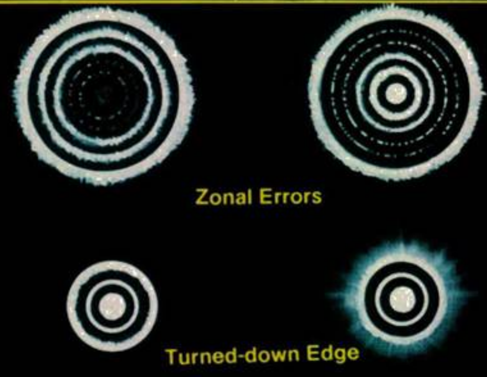
Poor Mounting

If, after aligning (or trying to align) your telescope, the image still doesn't approach the ideal image for its type, the next likely cause is poorly mounted optics. Refractors are seldom subject to

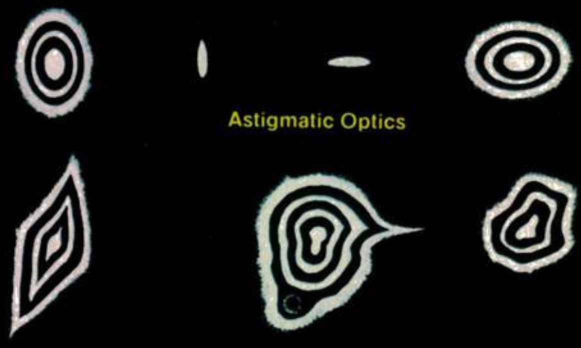
* Poorly Mounted Optics







* Poor Optical Figure



*Grossly Defective Optics

poor mounting (unless you have taken the lens apart and put it back into its cell incorrectly), but the mirrors of reflectors are often improperly mounted. A mirror should never be clamped or glued tightly into its cell; it must be free to move a tiny amount, or it may be flexed or distorted. An old rule-of-thumb that works well is to insert tiny slips of thin paper between the mirror and the cell to hold it when you adjust the clips and retainer, removing the papers afterward. This leaves a gap of .002 to .003 inch and insures that the mirror is not flexed. Of course, after checking the mounting of the optics, you'll have to realign the mirror again. (See "Tune Up Your Telescope", ASTRONOMY, December 1975.)

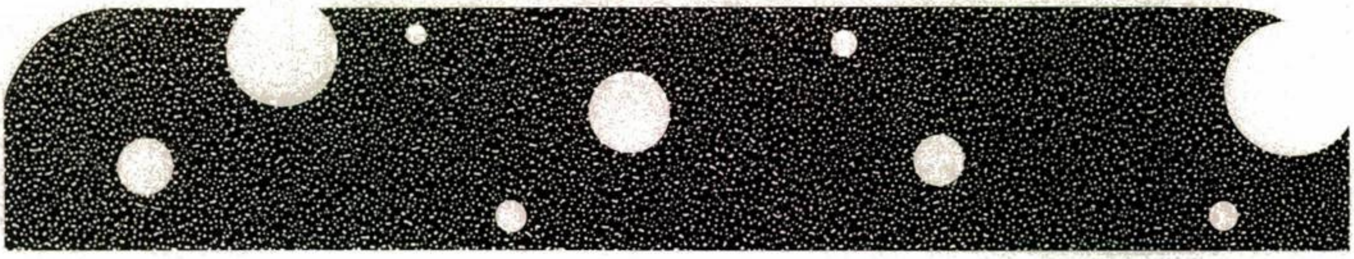
Poor Figure

Until now we've assumed that your mirror itself was good, but if it doesn't give good images after being aligned, the mirror (or in some cases, the refractor objective) may be at fault. The most sensitive test is to check the images both inside and outside focus to see if they are identical. If the "three ring" image looks like one of the drawings above, the mirror is not a perfect paraboloid shape, but is over- or undercorrected. Another type of problem called *zone aberration* makes some of the rings in a six or seven ring image look too dim or too bright. If the mirror is commercially made, you should complain to the manufacturer; if it's of your own making, you may want to improve it. In any case, this test is *very* sensitive, and defects that will never bother you during ordinary observing can show up. If you are generally satisfied with the images, don't worry about it.

When a mirror shows astigmatism, it was either incorrectly made, or poorly mounted. If it's not the main mirror, the diagonal may cause astigmatism; the diagonal, like the main mirror, should never be held tightly, stressed, or clamped in place.

A problem called *turned down edge* is rare in commercial telescopes, but common in homemade ones: The extreme outer edge of the mirror is too "low". The problem — a halo of light scattered around the image — can be rectified by painting the outer quarter inch of the mirror black. Turned down edge can be recognized easily in the out-of-focus image — because inside focus you see a halo of light, and outside focus, the edge of the mirror appears very bright.

Finally, badly distorted, warped or seriously defective optics may yield virtually any pattern — usually strongly asymmetric or irregular. Modern telescopes seldom show such effects except in the very cheapest equipment, but antique telescopes, made when glass was not as good as it is today, more often do. If you have an antique, of course, you may be content keeping it on display and observing with a more modern instrument.



Birthplaces of Stars

by
Michael Zeilik

Interstellar space is not empty, as was believed until this century. Dust and incredibly tenuous gas exist between the stars in huge quantities. Astronomers have detected interstellar dust because it reddens the light from stars, just as dust in Earth's atmosphere reddens the sun at sunset. Interstellar reddening cuts off a substantial amount of the starlight coming from the dense nucleus of our galaxy; hence the center of the Milky Way, in the direction of the constellation Sagittarius, shines as a faint cloud of light rather than a large blob as bright as our moon. Interstellar gas becomes visible when it is very close to hot stars, which ionize it and excite it to fluorescence. Radio astronomers can detect the un-ionized gas that emits radio waves at 21cm wavelength. Radio maps of the galaxy reveal that this un-ionized hydrogen sticks to the curve of spiral arms, outlined by hot, young stars.

The modern view of our galaxy recognizes that stars *evolve*. Here, we'll describe modern theoretical ideas of stellar formation and the search by infrared astronomers for the sites of cosmic wombs. An understanding of star formation provides an essential foundation toward understanding the varieties of star clustering — from binary systems to spiral galaxies.

The Eagle nebula (M-16) surrounds a cluster of stars believed to be only a few million years old. The hundreds of stars in this cluster are still wrapped in the clouds of dust and gas from which they formed. The dark globules in the nebula may be protostars — rapidly swirling gas in the process of condensing into new stars. M-16 and nebulae like it are primary targets in astronomers' search for stellar birthplaces. Photograph by Leo C. Henzl Jr.

Protostars: Collapsing Caldrons of Gas and Dust

When an interstellar cloud becomes dense enough, self-attraction begins to draw the particles in it toward each other. What can fend off the inward pull of these gravitational forces? If the material — hydrogen gas, for example — is hot, pressure pushes the material out, forcing expansion. Once the outward pressure forces and the inward gravitational forces balance, the system reaches equilibrium. However, collapse can take place only when the mass is sufficient to overcome the thermal pressure. Low temperatures help the collapse; the colder a gas cloud, the less mass is needed to initiate and continue its collapse. In order for interstellar matter to condense into stars, it must first be compressed into clouds massive and dense enough to upset its equilibrium.

Dense, dark clouds in and around the Milky Way — sometimes appearing as huge blots in front of stars (such as the Coalsack nebula) — have been found by radio astronomers to contain thousands of solar masses of material at temperatures about -440 to -370 degrees Fahrenheit (10 to 50 degrees Kelvin). Because of their large mass, these clouds cannot condense into ordinary, single stars. They must break up as they are squeezed to higher densities. The dark clouds observed so far show some hint of internal structure — possibly subcondensations breaking off from the larger mass. Because single stars exist in the galaxy, natural processes must somehow chop up the primordial cloud.

Theoretical calculations concerning star formation have made so many simplifying assumptions that they may not be very near to reality. Such approaches have centered on single protostars growing out of a round, nonrotating, nonmagnetic cloud. Such "manicured" models should show the general features of the gravitational collapse and draw attention to important problems to be solved. However, attention should properly be focused on a theoretical simple protostar model, with a few comments on rotational effects.

Imagine a cloud of gas, assumed to be mostly hydrogen in molecular form (H_2), with a dust content of about one percent. Newtonian gravitation theory predicts that a cloud with enough mass to overcome pressure forces will collapse in a time that is inversely proportional to the square root of its density. As the *first stage of contraction* continues, material at the cloud's center increases in density faster than the material at the edge. Because of the density increase, the collapse time for the center is decreased; it collapses faster, grows denser, and thus collapses still faster. This bootstrap effect shrinks the central core, which contains a smaller and smaller fraction of the cloud's total mass. The rest of the mass is left behind in a slowly contracting envelope whose size is only a little less than that of the initial cloud. Because of the irregular rate of collapse for the inner and outer regions, the cloud splits into a core and an envelope, which experience different dynamical histories.

The thermal properties of the cloud play an important role in the process of the core's collapse. As the material rapidly condenses, gravitational potential energy in the gas is converted to thermal (kinetic) energy. As the hydrogen molecules bounce around, they strike dust grains, stick and so transfer their kinetic energy to the solid particles. Heated by these collisions, the dust grains radiate at infrared wavelengths. As yet, the cloud isn't very dense, so the infrared radiation can speed out of the cloud into space. The rate of infrared radiation escape keeps the overall temperature low [about -440 degrees Fahrenheit (10 degrees Kelvin)]. As the central density increases, it reaches a critical value at which the cloud rapidly becomes opaque to infrared radiation. Trapped inside the cloud, the infrared radiation raises the temperature to a few hundred degrees Kelvin. The increase in temperature increases the internal pressure, which effectively balances the gravitational force so that a state of near-equilibrium is achieved.

Meanwhile, the envelope, knowing nothing of the events at the center, continues to fall inward, showering mass on the core. When the infalling material hits the static core, it piles up, increasing the core's mass and temperature. At about 3,000 degrees Fahrenheit (2,000 degrees Kelvin), the core reaches another critical stage, for the hydrogen molecules begin to break up, soaking up heat energy from the cloud. The temperature drops; the pressure decreases, and gravity takes command again, collapsing the core even more. At the start of this *second stage of contraction*, the core's radius is about four times the Earth-sun distance. At the end of this stage, the core will be about the same size as the sun. The completion of the second collapse phase is marked by the lack of further hydrogen molecules to break up. This heat sink is cut off, and as before, the gravitational potential energy feeds in energy to heat the cloud. The temperature climbs to 40,000 degrees Fahrenheit (20,000 degrees Kelvin), and the core attains equilibirium. During this second phase, the core's mass is enhanced by the accretion of infalling material — enough so that this kernel in the cloud can reach the temperatures necessary for the thermonuclear reactions that signal stellar birth.

As the core rapidly evolves to stellar status, the envelope continues its leisurely inward pace, marked by shock waves emanating from the core. This envelope screens the actual birth of the star from the view of the optical astronomer. The pangs of birth, however, generate telltale clues for radio and infrared observers. When a massive star initially "turns on", it is hot, and its ultraviolet radiation ionizes the hydrogen gas. (The shock waves rushing outward also help to ionize the gas.) As the free electrons whip around protons, they emit radiation at wavelengths that can be detected by radio telescopes. Therefore, a compact, optically invisible radio source is a prime indicator of a massive protostar. Additionally, the dust in the envelope snatches up most leftover ultraviolet photons, heats up, and emits infrared radiation with an equivalent temperature of a few hundred degrees Kelvin. An infrared source immersed in a dark cloud is another sign of starbirth.

Eventually, the envelope's shroud is discarded — either by its falling onto the young star, or by its ejection from the star's strong radiation pressure. As the veil lifts, the new star appears as a premain sequence object; that is, it is still more luminous than is typical for stars with its mass and chemical composition. Astronomers have coined the term *cocoon stars* for these fledglings still cloaked in a swirl of gas and dust. The formerly placid clouds emerge from their shells metamorphosed into a thermonuclear furnace destined to burn for (at least) millions of years.

Observations of Suspected Protostars

Astronomers have direct evidence that some stars have recently, in astronomical terms, been born. The Pleiades, for example, are still wrapped in their primordial cloud. Indirect lines of evidence have established the age of the blue-hot Pleiades as a few tens of millions of years. Other star clusters are known to be still younger. In the constellation Serpens, the bright nebula M-16 (the Eagle nebula) forms an irregular smear in the sky — a young cluster of hundreds of stars only a few million years old. Both these clusters present strong support for the theory of star formation in the fragmentation of massive collapsing clouds. To confirm this idea, astronomers are now scanning areas near bright nebulae with infrared telescopes in an attempt to find infrared sources that can be identified with developing stars. The apparent association (not yet completely confirmed) between protostars and H-II regions (nebulae of ionized gas such as M-16) is expected, since H-II regions are very young systems containing recently formed massive stars and left-over interstellar gas.

The infrared astronomer's task is not an easy one; he must cope with the opacity of Earth's atmosphere to infrared radiation. Water vapor and carbon dioxide contribute the most to the infrared opacity, leaving open only a few windows (infrared regions of relative transparency) for astronomical observations. Even these windows are clear only from places of high elevation and low humidity, such as the mountains in Arizona. The best sites still frustrate the infrared astronomer, however, because the available windows restrict the kinds of objects he can view.

We must assume most celestial infrared radiation comes from heated dust grains. The spectrum of radiation from hot solids has a characteristic shape — called a *blackbody curve* — with a peak intensity which depends only on the temperature of the emitting body. The wavelength at which a blackbody spectrum peaks is given by a simple relationship called *Wien's law* which states that as a blackbody's temperature decreases, the wavelength at peak emission increases. For example, a 1,000 degree Kelvin blackbody peaks in output at three microns; a 100 degree Kelvin body at 30 microns, and one at 10 degrees Kelvin puts out most of its energy at 300 microns. (A micron is equal to 40 millionths inch, or one millionth of a meter.) For celestial infrared observations, astronomers must choose the wavelength range that corresponds to the estimated temperature of the target objects.

Earth's atmosphere acts like wide bars on the windows that the infrared astronomer has into the universe, with water vapor allowing transmission in only a few regions out to about 20 microns. At great wavelengths, the atmosphere is essentially a dense smog until the radio region. Thus, ground based infrared observations are restricted to celestial objects hotter than a few hundred degrees Kelvin. We have pointed out that protostars may have just such temperatures. But in the early stages of gravitational collapse, a dense cloud heats up to only a few tens of degrees Kelvin. Earth's atmosphere inconveniently blocks the sight of the earliest stages of star formation.

With present technology, the obvious way around this problem is to get above it. Three methods are available: satellite, rocket and balloon. Although many people may think that an Earth-orbiting satellite fits the needs perfectly, they tend to forget that satellites are expensive, require long lead times for construction, and are difficult to repair after launch. Nonorbital rocket flights are much cheaper, but they send their small payloads to the proper altitude for only a few minutes and are difficult to orient with respect to celestial objects. Balloons offer the most reliable technique to place payloads above most of the atmospheric water vapor. The transparency gain compared to the ground is very great, for the opacity due to water vapor depends not only on the number of water molecules along the line of sight, but also on the water vapor line widths. The fewer molecules speeding around, the fewer jostles a molecule experiences, and the narrower the lines. As a result of few molecules and narrow lines, the infrared opacity decreases greatly. Relatively small balloons of about six million cubic feet can haul two ton payloads to over 90,000 feet for periods as long as a day.

Balloon astronomy has unique hazards involving launch and recovery. Large plastic balloons are fragile structures; strong winds can rip them along their seams. At launch, surface winds may also run a payload into a catastrophic crash with nearby trees. After a successful launch, the balloon may burst during ascent; 10 percent of all large balloons fall apart and drop their payloads. People can exercise no control over the parachute descent; scientific packages have landed in trees (destroying equipment), ponds (shorting out electronics), roads (creating a traffic jam), and backyards (frightening the residents). Worst of all, the parachute may not open when released from the balloon. The payload freefalls and splinters on impact with the ground.

But the advantages of ballooning — especially the low cost, long flights, and usual recovery of the package — have drawn infrared astronomers to this high-flying field. Beginning results from small telescopes sensitive to radiation from 50 to 350 microns have supported theoretical ideas about star formation. They find the Milky Way studded with bright far-infrared sources which, in contrast to the near-infrared emissions, do not coincide with stars, but with H-II regions. The character of the 50 to 350 micron emission from these turbulent, glowing masses is strikingly similar to that of the radio emission at the shorter wavelengths (around two centimeters). Typically, the infrared and radio emission contours coincide, and their coincidence occasionally corresponds to a bright optical knot in the nebula. Because the bright globules have a higher density, they are likely arenas of star formation. In such an active locality, a hot protostar ionizes the surrounding gas (producing radio emission) and also heats the dust, with the more distant grains at the cooler temperatures. Poor resolution hampers present infrared observations, but the cool dust (if actually surrounding the protostar) should appear as a bright infrared shell. The hotter dust closer to the incipient star should stand out at near-infrared wavelengths as a bright disk encompassed by the ring of cooler material.

On Feb. 3, 1974, the successful flight of a 40 inch balloon-borne infrared telescope — sponsored jointly by the Center for Astrophysics and the University of Arizona — marked a significant advance in probing the hideouts of star formation. Enclosed in a payload weighing over two tons, the 40 inch telescope is the largest aperture instrument ever placed above 98 percent of Earth's atmosphere (at 93,000 feet). This step up in telescope size provides a resolving power capability 10 times greater than previously achieved at far-infrared wavelengths (100 microns). In a recent flight this telescope detected a very strong infrared source east of the H-II region M-8. (This source has been named M-8 East.) Radio observers at the same location found a dense cloud of carbon monoxide molecules. These observations imply that a region of recent star formation — no more than a few thousand years old — is associated with M-8, an older region of star formation. Both M-8 and M-8 East appear to have condensed out of the same molecular cloud.

Cosmic Consequences

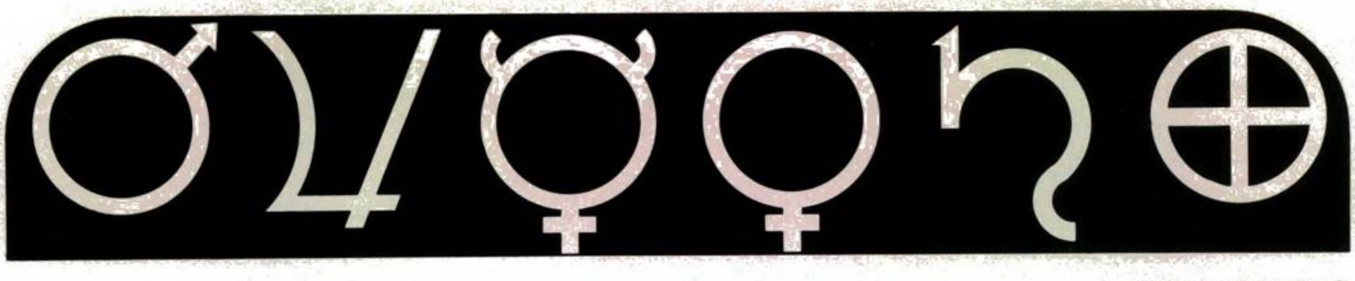
Most of the stars in the Milky Way are not solitary travelers through space, but are usually paired with another star, and occasionally grouped in larger systems. We should expect to find stars in groups, rather than alone, from the fact that only clouds with thousands of solar masses are dense enough to collapse gravitationally and begin star formation. The question is: How do these clouds split into many components? What is the course that leads to a lone star rather than a cluster?

The explanation depends on the cloud's rotation (its angular momentum). Physicists believe that angular momentum is a conserved quality in the universe. The principle of the conservation of angular momentum requires that the amount of angular momentum in a system remains the same unless an outside force torques the system. A collapsing cloud in interstellar space meets the criterion of an isolated system quite nicely; few outside forces are nearby. Because the cloud begins rotating with the galaxy, it has some initial spin and therefore angular momentum. The clouds shrink due to gravity and rotate faster to conserve angular momentum. This increase occurs only in the direction perpendicular to the spin axis; parallel to the axis, the cloud's material simply settles in gravitationally. The cloud flattens along the spin axis changing from a sphere to a disk. A dense nucleus grows up in the center of the disk; at the same time, the gas and dust heat up. The combination of collapse motions, rotational influences and heat churns up the cloud to develop turbulent eddies. If any eddy becomes dense enough, it will undergo its own collapse independently of the rest of the cloud, although still conserving its own angular momentum. A breakup of the original cloud into fragments of roughly the same mass and angular momentum results in a cluster of protostars that eventually evolve into a star cluster such as the Pleiades.

Much the same process applies to clouds of smaller mass that develop into systems of one, two, or a few stars. But how can a cloud of such small mass ever begin collapsing? This vexing question appears to have an answer in the galaxy's spiral structure. Associations of young stars and extensive clouds of un-ionized hydrogen gas mark the galactic spiral arms. Such a correspondence naturally suggests that the spiral arms arise as a consequence of — or perhaps are themselves — the cause of star formation. In the contemporary view, somehow the phenomena responsible for galactic spiral structure trigger collapse and star formation processes. The basic relationship between the emergence of new stars and the formation and stability of spiral arms rises from the density-wave theory of structure. This recent theoretical approach joins the simple idea of a density wave (a sound wave is a common example of a density wave) with the form of a spiral galaxy. As the wave moves through the interstellar medium, a shock front pushes ahead of it and compresses the interstellar medium like a piston. Small condensations accompany the passing of the shock wave; these evolve into single stars and other smaller star systems. Alpha Centauri, the nearest star to the sun, is the brightest member of a multiple star system.

Note that stars can develop from condensing clouds only if they have enough mass — about 0.8 times the mass of the sun. What of those luckless clumps that don't have enough mass to burn as stars? They become planets. Our solar system provides a good example, if not typical of the range of planetary characteristics. The behemoth Jupiter with its cyclopean eye is still shrinking gravitationally; the contraction generates excess heat detectable by terrestrial telescopes. Composed mostly of hydrogen and helium, Jupiter is most likely the stillborn twin of the sun. Speedy Mercury is the densest planet known, and observations indicate that its interior consists almost entirely of iron and nickel. Earth swings around the sun in its slow, close dance with the scarred moon.

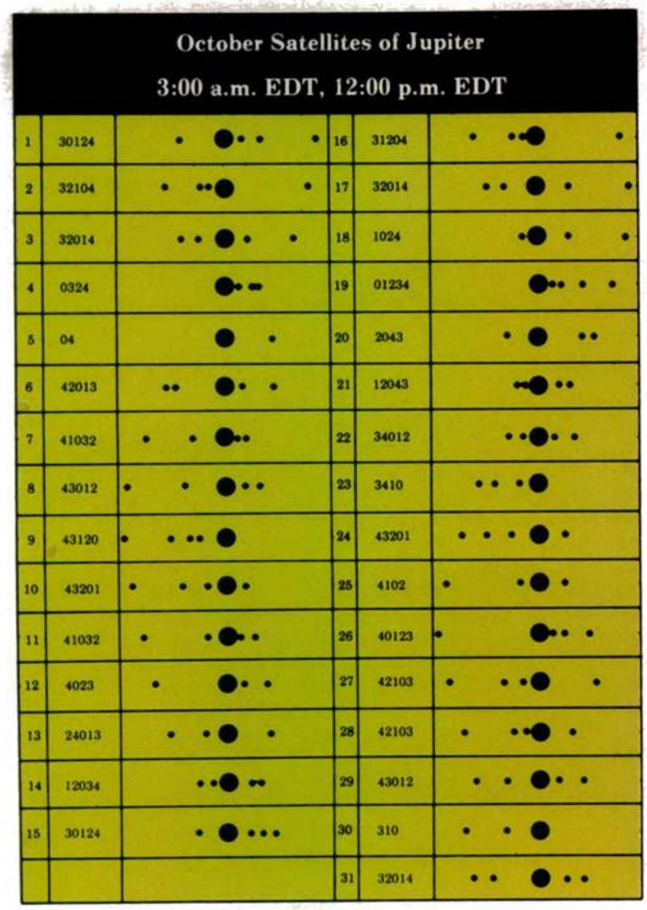
This celestial circus emerged from a cocoon of gas and dust some five billion years ago. Born with the sun, Earth is still tied by the umbilicus of energy to the sun's ultimate fate. The sun's history has been ours. In times past, a shock wave thundered through this part of the galaxy. It heated, fragmented and condensed the interstellar medium. In the resulting turmoil, one blob of material broke off, contracted, and became a star. The infrared energy from such lukewarm sources flags the most important of events in the galaxy: the ignition of stars and initiation of planets. These are the targets of the infrared astronomer's search for the birthplaces of stars.



SKY ALMANAC

Orionids and Other Objects

October is a month of changes. The summer constellations are replaced by the winter constellations; the sun sets earlier each day making it a little easier to do some observing before getting settled for the evening. Daylight Savings Time comes to an end, providing an extra hour for observing — which may come in handy toward the end of the month during the Orionid meteor shower. Observers in the southern hemisphere will be treated to a solar eclipse on the 23rd. Last month's harvest moon is replaced by this month's hunters' moon. And the good old standby planets, Venus and Jupiter, are there to trifle around with.



October Satellites of Jupiter

3:00 a.m. EDT, 12:00 p.m. EDT

1	30124	• ●• • •	16	31204	• ••● •
2	32104	• ••● •	17	32014	• • ● • •
3	32014	• • ● • •	18	1024	•● • •
4	0324	●• ••	19	01234	●•• • •
5	04	● •	20	2043	• ● ••
6	42013	•• ●• •	21	12043	••● ••
7	41032	• • ●••	22	34012	• •●• •
8	43012	• • ●• •	23	3410	• • •●
9	43120	• • •• ●	24	43201	• • • ● •
10	43201	• • •●•	25	4102	• •● •
11	41032	• •●• •	26	40123	• ●• • •
12	4023	• ●• •	27	42103	• • •● •
13	24013	• •● •	28	42103	• ••● •
14	12034	• •● ••	29	43012	• • ●• •
15	30124	• ●•••	30	310	• • ●
			31	32014	• • ● • •

The four major satellites of Jupiter orbit the giant planet in periods ranging from just under 2 days to 17 days. They can be seen to change position from night to night. Sometimes their motions become evident after only a few minutes' observation. Only a small telescope is required to detect all four of the satellites and several can frequently be seen in rigidly held binoculars. This table shows the approximate positions of the moons at about 3 a.m. (EDT) on the evenings indicated. First column on the left shows the date. Second column of numbers identifies the moons and their positions relative to Jupiter's disk. (1=Io; 2=Europa; 3=Ganymede; 4=Callisto, and 0=Jupiter's disk.) The third column approximates a telescopic view of the satellites' positions. The orientation of the satellites is shown inverted as seen in a standard astronomical telescope.

Mercury

In the early part of the month, the solar system's innermost planet will be at greatest western elongation, its largest angular distance from the sun. The western elongation will be the last of its type this year. Mercury's final eastern elongation will be in late December.

The elongation will occur on Oct. 7 when the planet will be approximately 18 degrees above the horizon. Orbiting at a distance of 86,500,000 miles from Earth, Mercury will be at -0.4 magnitude; thus it should be visible until the latter part of the month. At elongation, 34 percent of the planet's disk should be illuminated, increasing to 98 percent as it swings back to the sun for its superior conjunction in early November.

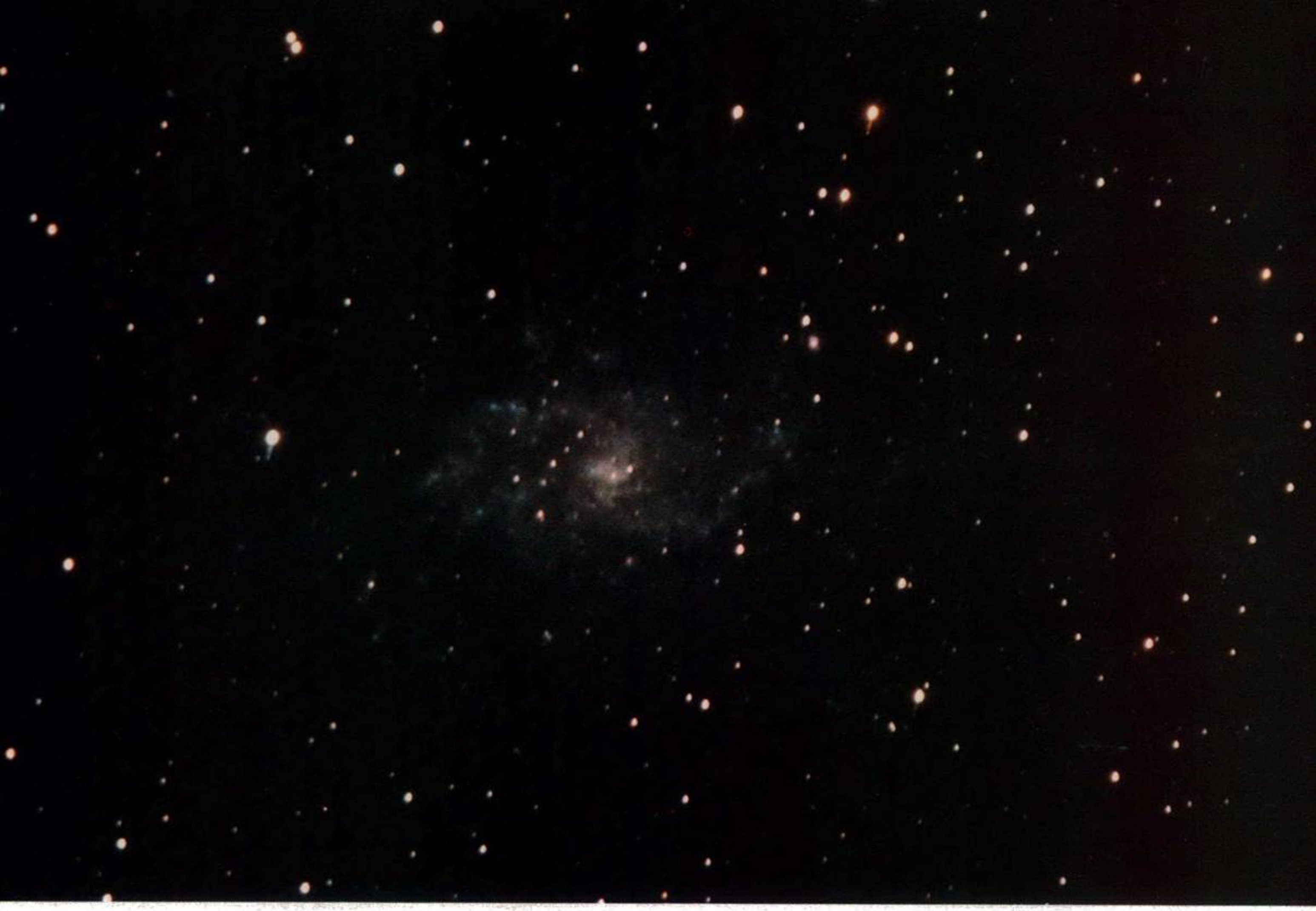
Venus

Early evening hours are the best time to observe Venus this month. At sunset, Venus should be about 10 degrees above the western horizon. It will shine at magnitude -3.4, making it the brightest object — other than the moon — in the night sky. On the 25th, Venus will be four degrees south of the two day old moon.

Jupiter

The giant planet dominates the night sky, rising about two hours after sunset. At magnitude -2.4, it rivals Venus (which sets in the west an hour before Jupiter rises in the east) in magnitude. During October, each planet dominates the night sky separately; but in November, they will share the celestial spotlight for about two hours after sunset.

Jupiter, situated in the constellation Taurus, will be having one of those close passes with the moon on the 11th of the month. The moon — which will be four days past full — will pass one degree south of the planet.



Two nearby spiral galaxies — both members of the Local Group, and both high in the sky during October — are seen in these photographs. At right is a close-up of the nucleus of M-31, the giant spiral in Andromeda. M-31 is estimated to contain about 320 billion stars — more than twice as many as the Milky Way. Huge lanes of dust reach out from the nucleus and coil around the galactic center. These dark lanes, all but invisible even in large apertures, are well seen in this 60 minute exposure on High Speed Ektachrome film, using a cold camera and an eight inch Schmidt-Cassegrain telescope at f/10. Photograph by Leo C. Henzl Jr. Above is a photo of M-33 in Triangulum, the most distant known member of the Local Group. More tenuous than M-31, M-33 is harder to see and more difficult to photograph. This 30 minute exposure on High Speed Ektachrome was obtained with a cold camera and a home built 12.5 inch reflector at f/4.5. Photograph by Greg Griffith.

Saturn

Saturn rises in the early morning sky at about midnight. In October the planet remains at magnitude +0.6, but will brighten as the months progress.

Satellite Shadows on Jupiter

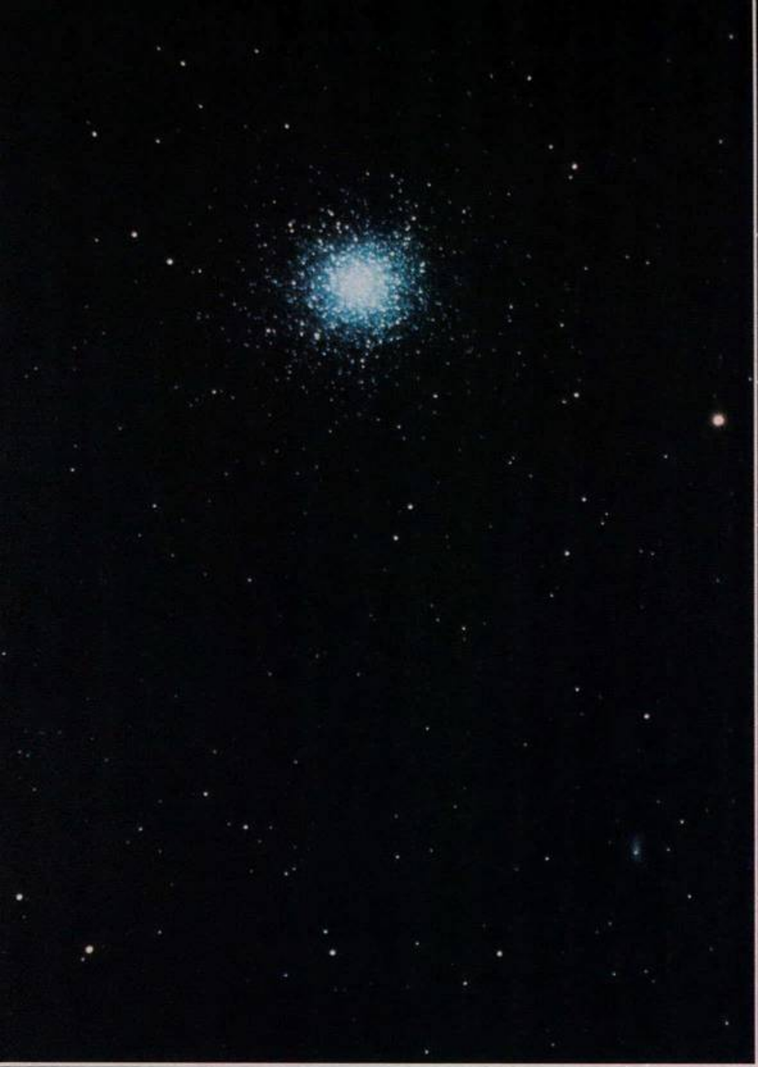
Date	Satellite	Transit Begins (EDT)	Transit Ends (EDT)
Oct. 1	3	2:20 a.m.	4:30 a.m.
4	1	6:35 a.m.	8:43 a.m.
6	1	1:03 a.m.	3:11 a.m.
	2	4:24 a.m.	6:58 a.m.
7	1	7:31 p.m.	9:40 p.m.
11	1	8:28 p.m.	10:37 p.m.
13	1	2:57 a.m.	5:05 a.m.
14	1	9:25 p.m.	11:34 p.m.
16	2	8:19 p.m.	10:53 p.m.
20	1	4:50 a.m.	6:59 a.m.
22	1	12:19 a.m.	1:28 a.m.
23-24	2	10:56 p.m.	1:30 a.m.
27	1	6:44 a.m.	8:53 a.m.
29	1	1:13 a.m.	3:22 a.m.
30	1	7:41 p.m.	9:51 p.m.
31	2	1:33 a.m.	4:07 a.m.

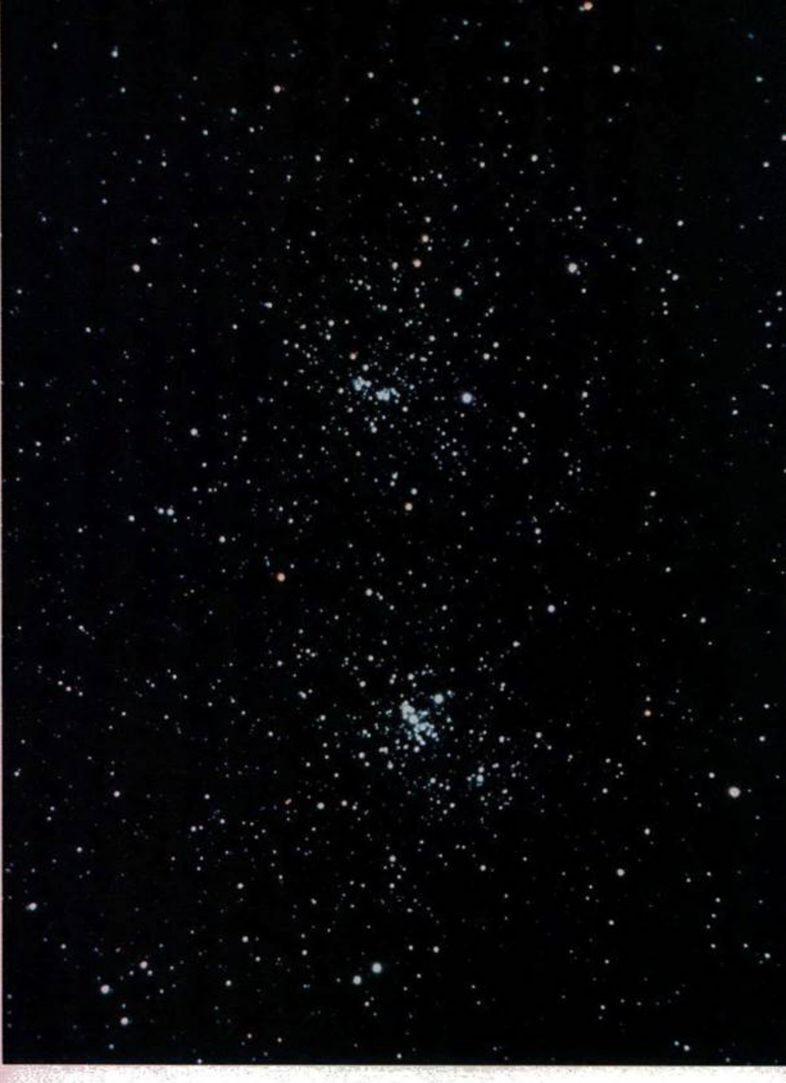
1 = Io
2 = Europa
3 = Ganymede
4 = Callisto

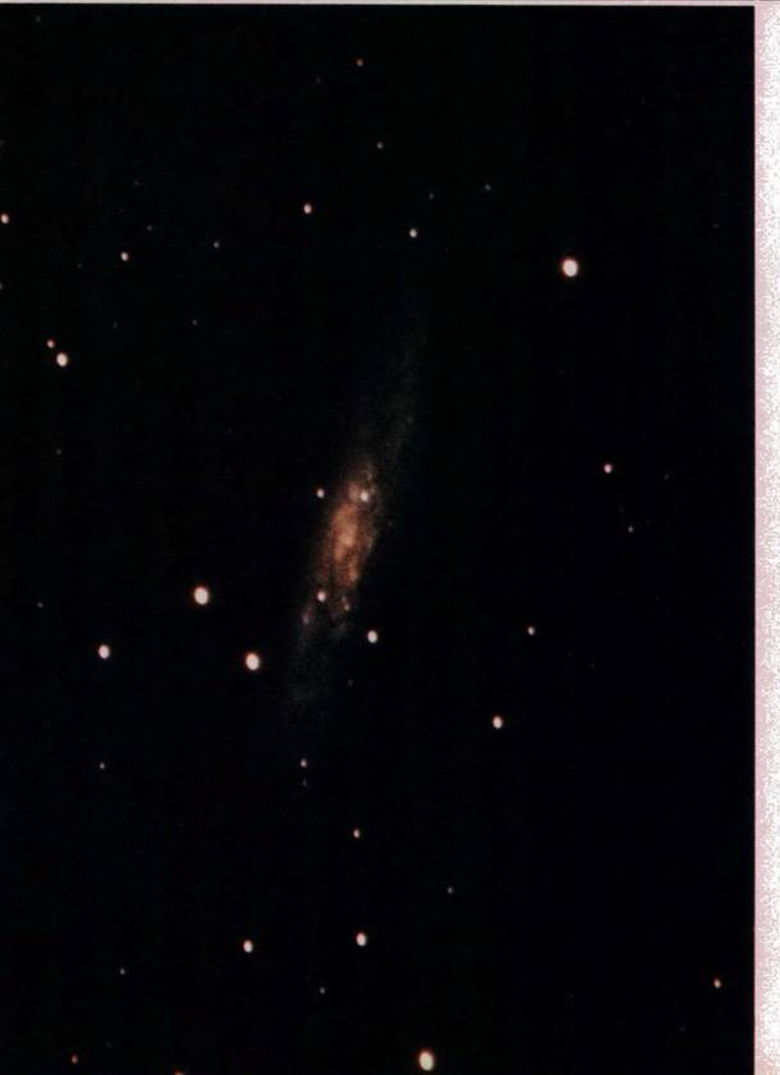
Saturn, in the constellation Cancer, is currently moving eastward and will begin retrograde motion among the stars in November.

Uranus

This month, Uranus continues its eastward trek among the stars. On the 17th, the green planet will pass near Lambda Virginis. On that date, Uranus will be only three minutes of arc south of Lambda. Observation may be rather tricky as Virgo rises approximately one hour before the sun, with Uranus at magnitude +5.7 and Lambda at +4.6. If you can find Lambda Virginis — low in the dawn sky — shortly after it rises, you'll get a glimpse of Uranus closer to the sun than is usually possible, making an unusual wide "double star". You'll have







The best known of all globular clusters, M-13, is seen in the photograph at upper left. More than 200,000 light-years away, M-13 may contain a half million stars. The cluster is very old — perhaps 14 billion years — but for some reason contains a few young blue stars. In the same photograph is the 11th magnitude spiral galaxy NGC-6207, located about 40 minutes of arc from the cluster. This 40 minute exposure on High Speed Ektachrome was made with a cold camera and an eight inch Schmidt-Cassegrain telescope at f/10. Photograph by Leo C. Henzl Jr. Upper right: The Double Cluster (NGC-869 and NGC-884) is located in the constellation Perseus. These two beautiful clusters, both visible with the naked eye, are associated with each other in space: Both lie at a distance of about 7,200 light-years, and each contains about 300 stars. A five inch Schmidt-Cassegrain telescope at f/10 and a cold camera were used to obtain this 30 minute exposure on High Speed Ektachrome film. Photograph by Leo C. Henzl Jr. Lower left: NGC-253, a spiral galaxy located in the constellation Sculptor, is one of the brightest known galaxies, shining at magnitude 8.9. It is presented to our view at an angle that gives it an apparent length of 24.6 minutes of arc and a width of 4.5 minutes. The nucleus is small and the spiral arms more prominent. This is a 30 minute exposure on High Speed Ektachrome, made with a 12.5 inch reflector at f/4.5 and a cold camera. Photograph by Greg Griffith. Opposite page: Comet d'Arrest reached perihelion on Aug. 12, 1976. This periodic comet reached a magnitude of about six — fairly bright for a comet, but far overshadowed by the unusual phenomenon of comet West. These two photographs of the comet were taken just before its perihelion date. At left is a 15 minute exposure made on July 21; Kodak 103aF film was used for this shot through a 12 inch reflector at f/6. On Aug. 2, the comet had grown larger and brighter, as seen in the photo at right, made with the same film and exposure time. Photographs by Jean-Guy Moreau.

about 15 minutes of viewing before the light of the approaching sun obscures it.

Orionid Meteor Shower

Meteor shower observers may have been disappointed when the full moon cut down the number of observable Perseids, but the Orionids should pacify them.

The new moon is only two days after the 21st of the month, which is the day the maximum number of meteors will be visible. The shower will last from Oct. 16 through the 27th, with meteors radiating from the constellation Orion at a rate of 25 per hour. The radiant is located in northeastern Orion not far from Gamma Geminorum, on a line from it to Betelgeuse. The Orionids are one of the fastest of the yearly showers; its meteors cut through the atmosphere at a velocity of 106 miles per second (66km/second). The shower is also known for the persistent trail the meteor leaves as it crosses the sky, often visible for several seconds.

Solar Eclipse

Observers in the southern hemisphere will be treated to a total eclipse of the sun on Oct. 23. The eclipse will begin in East Africa, continue across the Indian Ocean and the southern part of Australia, and end in the South Pacific. These portions of Earth will be in total darkness for about 4.9 minutes — a relatively long period of time for a solar eclipse, because the duration of totality can never exceed 7-1/2 minutes. The next solar eclipse that will last over five minutes won't occur until June 1983, and there won't be a seven minute eclipse until July 1991.

Daylight Savings Time Ends

Oct. 31 signals the end of Daylight Savings Time for 1976. Traditionally it begins on the last Sunday in April and ends on the last Sunday in October. The difference between Daylight and Standard Time is that for Daylight Time, the time zone is shifted eastward one hour. If someone in a Central Standard state shifted to Daylight Savings Time, their time zone would be the same as Eastern Standard Time. Therefore, on Daylight Savings Time, the sun rises and sets an hour later than Standard Time. The major advantage to this time shift is that the demand for energy is decreased because people sleep "later" in the morning and have an additional hour of light in the evening.

Hunter's Moon

Last month Sky Almanac featured a detailed explanation of the harvest moon. This month the same principle is at work, only to a lesser extent. The moon, which is called the hunters' moon, rises earlier than the average 51 minute delay but not as early as the harvest moon. Traditionally, hunters pursued their quarry by light of this moon which lit up the night sky for several successive evenings.

The Man-of-the-Light-Year at Meade Instruments is Nicholas-Louis de Lacaille

It was he who first espied 87 naked eye stars in the mid-18th century South African skies. What's more—he resisted the temptation to name them for some time-worn demi-gods and -goddesses. He is very special to us not because this was a landmark sighting in the history of astronomy. Hardly. Rather it's because he made a constellation of a nondescript array of stars and called it "Telescopium".

Perhaps it seems a bit obvious for a telescope designer/manufacturer to capitalize on a sprinkling of stars that you have to force yourself to see as a telescope constellation.

Well, we don't blame anyone these days for being advertising-shy. But this is the way we happened onto our Man-of-the-Light-Year.

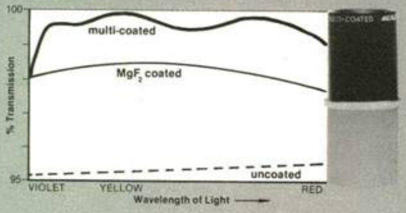
At Meade Instruments we're always taking a long, hard look at our products. At the way they meet the stringent requirements of serious amateur and professional astronomers. At the way they assemble into finely-meshed instruments under the gun of dead-eye tolerances. At the way they smoothly integrate themselves into our own telescope systems and even enhance the finest systems built by our competitors.

Like Lacaille, we are always on the alert for new and more exciting constellations that can be made with our components. This takes some doing when so many of our fine instruments are stars of such impressive magnitude that we might overlook the larger picture. Whenever this is about to happen we will get a call or visit from a customer who has been scanning our ads and not seeing the system for the components.

Together we make a sighting of his own Telescopium—the optimum interface of several Meade components. Our customers tell us that a helpful word or two of our technical counsel has saved them countless hours of unproductive ad-scanning.

Taking another leaf from Lacaille we call your attention to the system orientation that governs all our design and manufacturing—of everything from a color filter to a full-blown refracting telescope.

Our exclusive Meade Research-Grade Orthoscopic eyepieces are a case in point. To begin with, they are superior 4-element optical systems in their own right. As such, they are unsurpassed for color correction, resolution, and flatness-of-field. The lenses are figured to incredibly exacting tolerances and are 5-layer Multi-Coated to maximize light transmission and increase image contrast. The extent to which Multi-Coating enhances light transmission can be readily seen in the comparative curves.



For another thing, all six of our Research-Grade eyepieces are precisely parfocal: the observer need not re-focus the image each time he switches from one eyepiece to another.

And oh — a belated thanks to you, Nicholas-Louis de Lacaille. May your star shine brightly in the astronomer's firmament. Without you, we couldn't have made such a telling point about Meade optical systems.

PRODUCT DATA

1 - PHOTO-VISUAL COLOR FILTERS - Top quality optical glass, dyed in the mass, with excellent spectral homogeneity. Mounted in machined metal cells which thread directly into all our 1-1/4'' "Series 1" and "Research-Grade" eyepieces. Filters may be piggybacked. Listed by Wratten No. and color:
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3 - Series 1 PARFOCAL ORTHOSCOPIC EYEPIECES (1-1/4'' O.D.) - As in (2) but parfocalized in all 8 focal lengths. **Each:...$18.95 ppd. - Set of any 4:...$72.95 ppd. Set of any 5:...$90.00 ppd. - Additional eyepieces: each...$18.00 ppd.**

4 - RESEARCH-GRADE ORTHOSCOPIC EYEPIECES with Multi-Coated, Parfocal Optics (1-1/4'' O.D.) - Acclaimed by amateur and professional astronomers everywhere to be the world's finest eyepieces. These 4-element systems are unsurpassed in resolution, color correction, and flatness of field. Air-to-glass surfaces are 5-layer multi-coated for maximum image contrast and light transmission. 45° field. Precisely parfocal. Barrels are threaded to accept our filters directly. **Focal lengths: 4, 7, 10.5, 16.8, 28mm each...$29.95 ppd. - Set of any 4:...$112.50 ppd. Set of any 4 plus Res. Gr. Erfle 20mm...$137.50 ppd. - Full set of 5 Res. Gr. Orthoscopics plus Res. Gr. Erfle 20mm...$165.00 ppd.** (Sets of 4, 5, or 6 eyepieces are shipped in fitted carrying case (see (27) at no additional charge).
RESEARCH-GRADE ERFLE 20mm (1-1/4'' O.D.) - Parfocalized with our Research-Grade Orthoscopics and 5-layer multi-coated. Apparent field in excess of 75° for breathtaking wide-angle observations. Barrel accepts our filters directly. **$36.50 ppd.**

5 - Series 1 KELLNER EYEPIECES (1-1/4'' O.D.) - Highly corrected, 3-element design, fully coated. The best in moderately priced eyepieces. Barrels threaded for our filters. **Focal lengths: 6, 12, 25mm each...$11.50 ppd. - 40mm Wide Field...$13.50 ppd.**

6. - KELLNER 40mm EXTRA-WIDE-FIELD (1-1/4'' O.D.) - Yields widest field obtainable in 1-1/4'' O.D. Enlarged field lens and special field-flattening optics with long eye relief. Barrel accepts our filters... **$22.75 ppd.**

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8 - ZOOM ORTHOSCOPIC EYEPIECE (1-1/4'' O.D.) - Zooms instantly from 8.4mm to 21mm, with excellent image corrections at all powers. Wide 50° field at 8.4mm. Fully coated optics...**$32.95 ppd. - Filter adapter #004**: couples our filters to above eyepiece...**$1.00 ppd.**

9 - ZOOM KELLNER EYEPIECE (.965'' O.D.) - Fine 4-element design. Zoom range 7.5mm-22.5mm. Fully coated optics...**$24.95 ppd.**

SUPER-WIDE-FIELD EYEPIECES (2''O.D.) - Premium-quality wide-field eyepieces for 2'' focusers. The ultimate in rich-field performance. Fully coated.
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11 - KELLNER 60mm (2'' O.D.) - Low power, long eye relief. Ideal for deep-space observations...**$29.50 ppd.**

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13 - .965'' EYEPIECES - (phone, or request catalog, for details).

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Micrometer Reticle: Full-field scale for accurate measurements of double star separations, planetary angular diameters, etc. Interchanges with standard 4-line reticle...**$11.95 ppd.**

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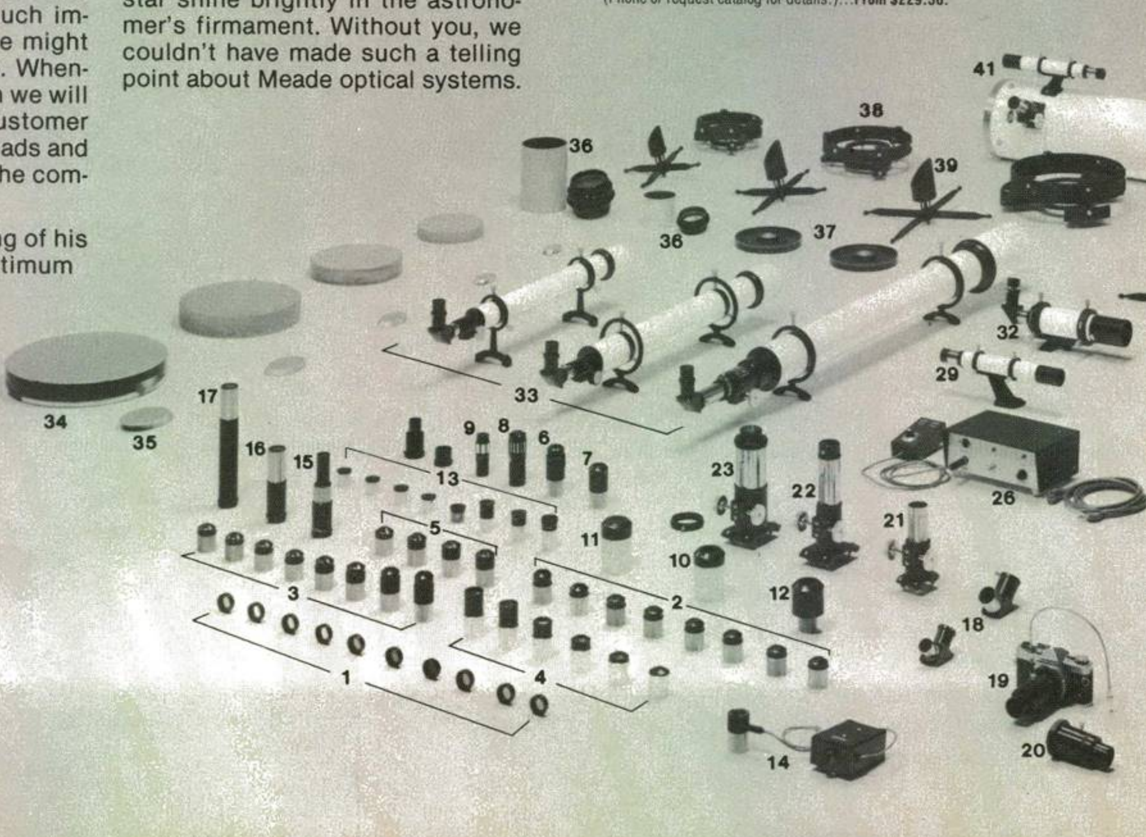

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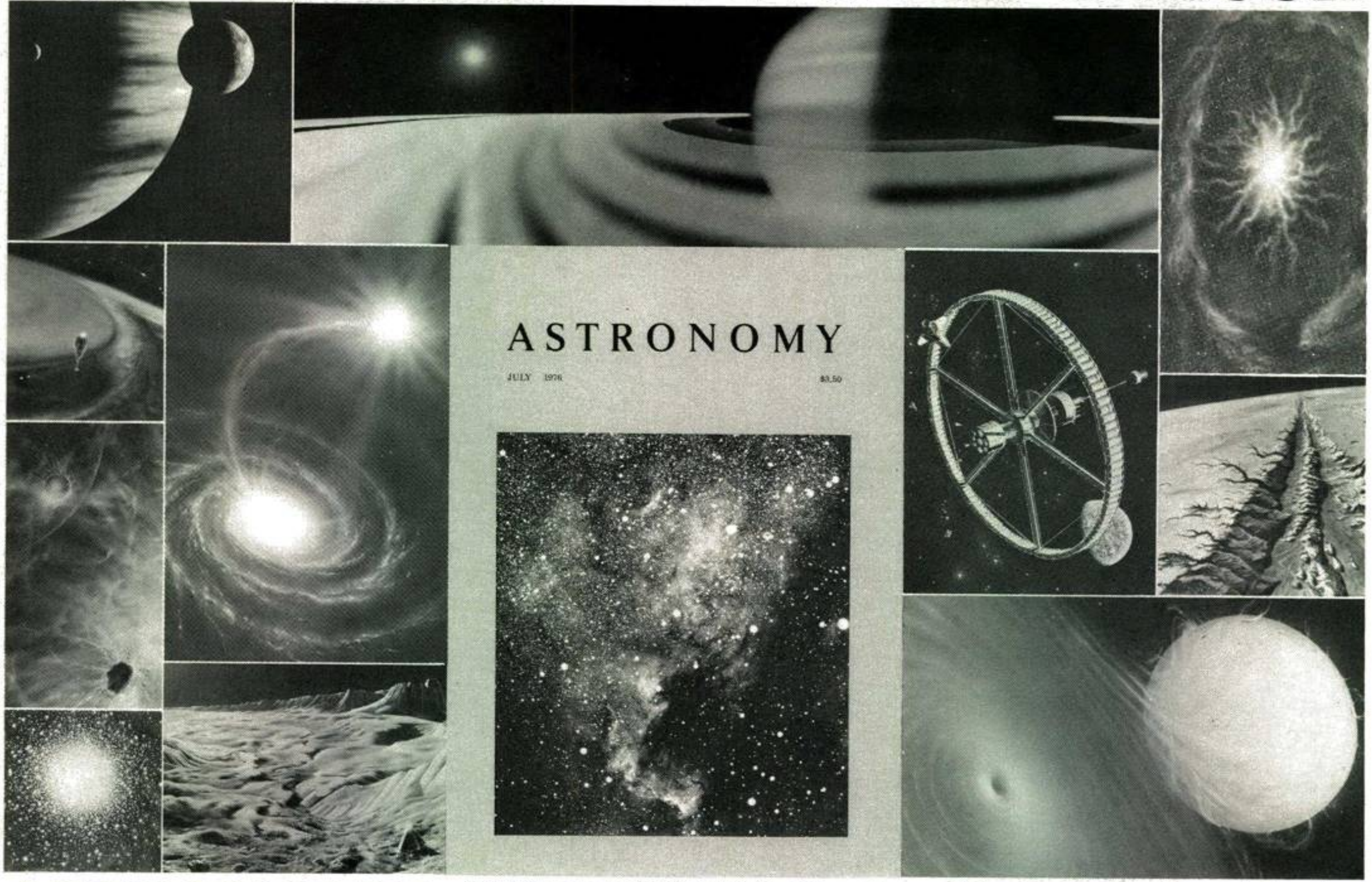

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LOOK NORTH FOR AURORAE

by
Richard Berry

As the solar maximum of 1980 approaches, observers — especially in the northern states and Canada — will be treated to an increase in auroral activity. Aurorae (caused by atomic particles emitted from "active" regions on the sun) are closely tied to the solar activity cycle; thus, as solar activity increases, you can confidently expect to see more aurorae.

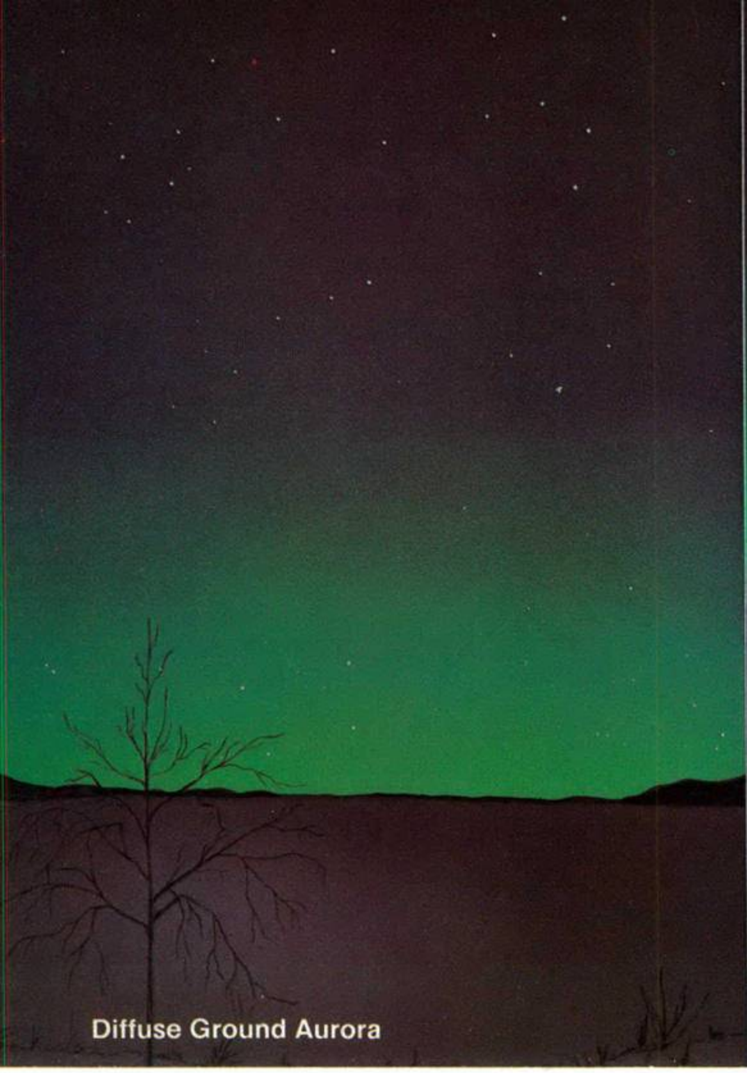
Normally, when aurorae are mentioned, an image comes to mind of the brilliant, multicolored displays that are widely photographed and reported — but such spectacles are actually fairly rare. Far more common are the little aurorae that begin as a soft glow in the north, develop a bit of structure or detail, and then vanish as unobtrusively as they came. You may have seen such aurorae without knowing it — dismissing it as some kind of funny cloud or haze — but if you know what to look for, they're not hard to recognize. It's a good idea to get in the habit of keeping an eye on the sky in the north — just a quick check every hour or so — to see if an aurora is lurking.

Basic auroral forms are *glows, arcs* and *bands,* which may occur either with or without ray structure. A glow is just what it sounds like: a big patch of sky that lights up but shows no obvious shape or detail. If a glow occurs along the horizon, it is called a *diffuse ground* aurora. Sometimes the glow will not be right on the horizon but anywhere from 5 to 50 degrees high in the north, in which case it's called a *diffuse surface*.

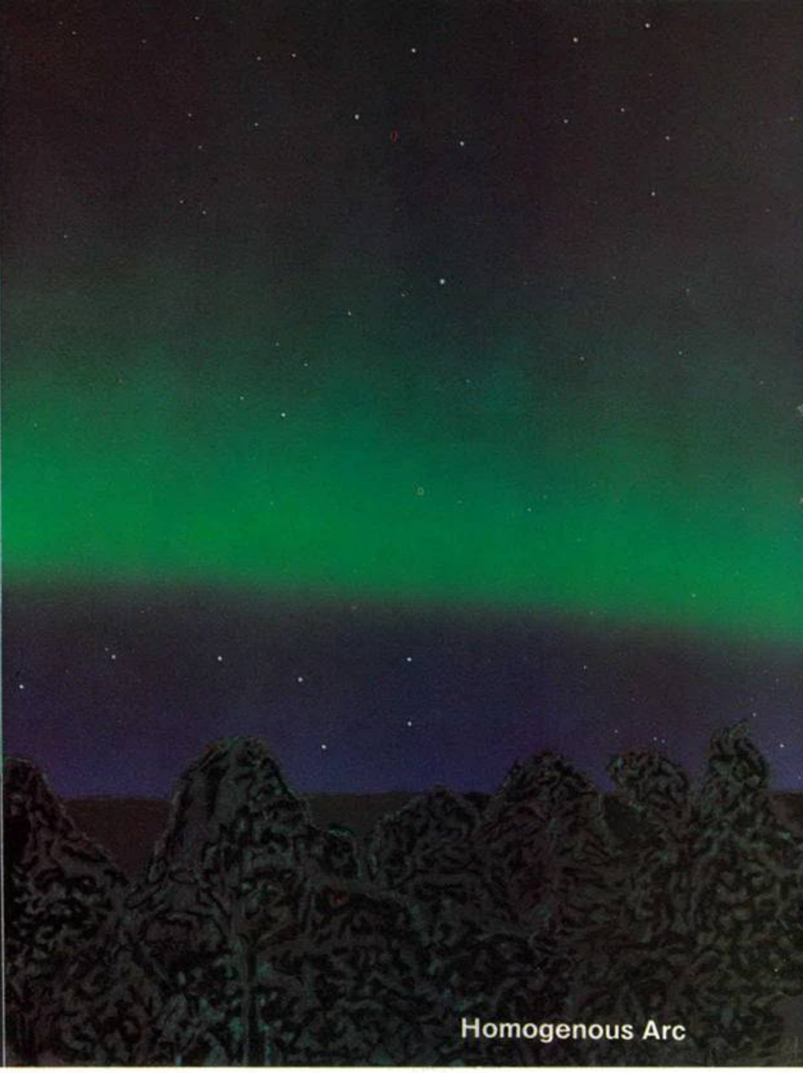
An arc is another common form. Much easier to distinguish than a faint glow, it appears as a low bridge of light spanning the northern sky. While most arcs do not extend very high in the sky — only 10 degrees or so — they may span 120 degrees of northern heavens. Usually, the bottom edge is sharply defined while the upper side tapers off gradually. An arc will sometimes first appear very low in the north and slowly grow higher and brighter for a few hours before a big display breaks; thus, if you've been keeping a watch on it, you can be ready with your camera. An arc without other distinguishing features is called a *homogenous arc.*

If an arc is not symmetric, but develops a kink or fold (or perhaps many folds), it is called a band. An arc may evolve into a band or several bands during the course of an evening. The bands often move and shimmer, as if being blown in a gentle celestial breeze, as solar particles create the different patterns in Earth's upper atmosphere. If a band has no other distinguishing features, it is called a *homogenous band.*

Each of the three basic structures can be modified by several additional features such as *rays, pulsations* and *flames.* Rays are the most common: An arc or a band, instead of being a continuous smooth stream of light, appears to be made of streaks pointing toward the zenith. Weak rays may be barely visible at all in an arc or band, while some arcs and bands may have no continuous structure at all, consisting entirely of rays. An arc with rays is called a *rayed arc*, and a band with rays is called a *rayed band.* Rayed arcs usually start as homogenous arcs, and then slowly develop little modulations in brightness that eventually become visible as rays. Some of the rays may be short while others are



Diffuse Ground Aurora



Homogenous Arc

Diffuse ground aurorae can be difficult to distinguish from city glows on the horizon. But unlike city lights, aurorae often evolve and change during the night. While a homogeneous arc may masquerade as a cloud band in the north, it does look different: The band is diffuse especially on the top, while cloud is usually sharp-edged. As the night progresses, a homogeneous arc usually moves higher in the sky. Artwork by Mark Paternostro.

longer. If a band develops many long rays, the rayed band looks like the bottom edge of gigantic celestial curtains swinging in the air; in this instance, it is called a *drapery*.

If the underlying feature is very faint, the rays will appear by themselves, either as single rays or in ray bundles. A dramatic but typical appearance of rays may be 10 to 20 rays spread across the sky at an altitude of 30 degrees — each ray thin and sharp — turning slowly on and off. Such displays are called *picket fence* aurorae.

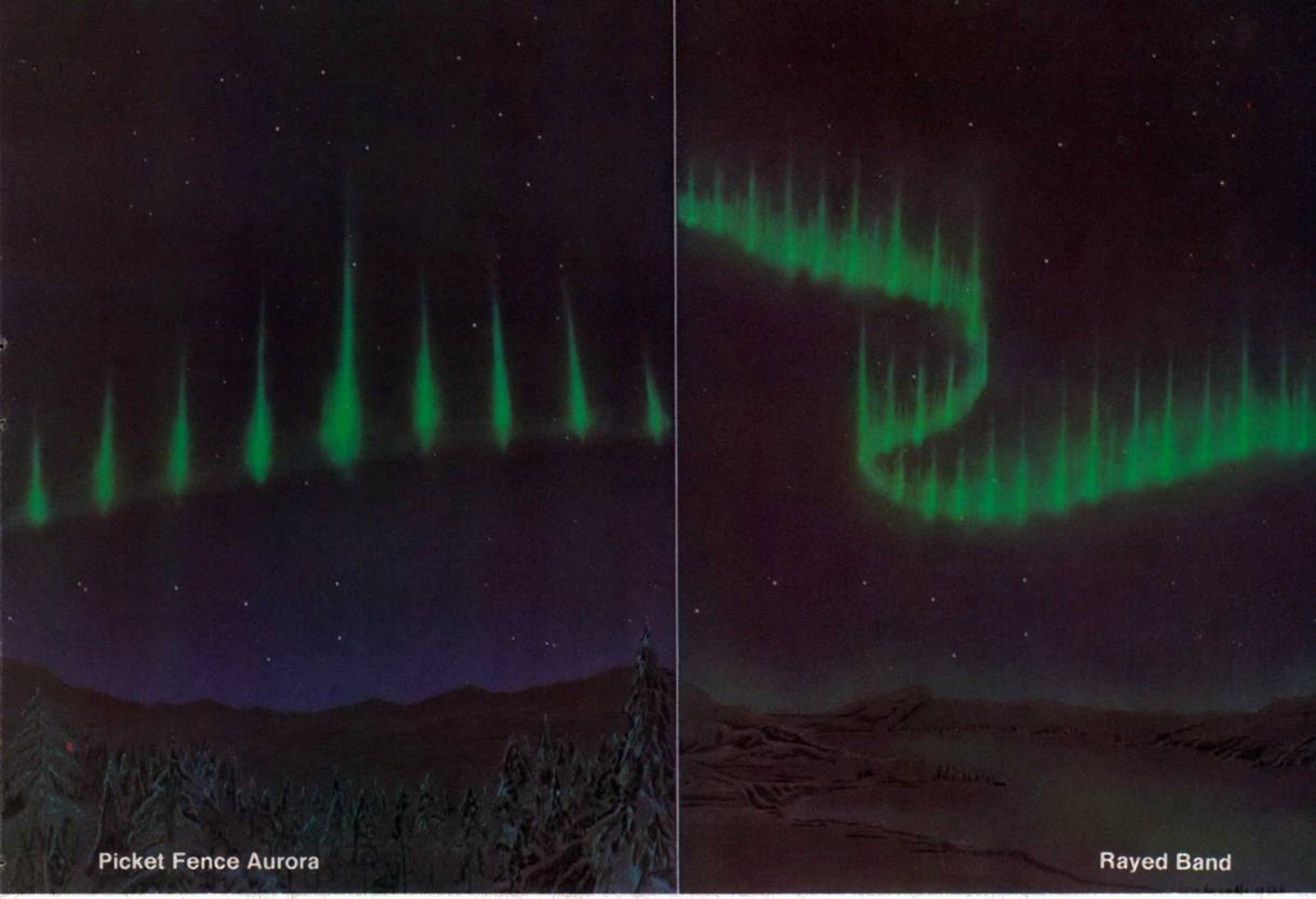
Pulsations add an exciting element to auroral observation, because an entire display such as picket fence aurorae may go on and off several times a minute! Or sometimes most of the rays will go off, leaving just a few on. The underlying form seems to remain in the same spot; however, the supply of atomic particles from the sun may not be continuous, so the light of the aurora will flicker. Glows are much more steady (taking 5 or 10 minutes to come on or go out), and so are most arcs and bands.

An odd type of aurora you may occasionally see is the *pulsating diffuse surface*, which often appears as an oval or ellipse. Quite suddenly, a glowing oval may appear in the sky, growing brighter and pulsing in brightness, and then disappearing in a minute. A few minutes later, it might reappear, repeat its performance and disappear! Such a sight may surprise even experienced observers.

If pulsations happen quickly and waves of light seem to move toward the zenith, an aurora is said to be flaming. Flaming aurorae are usually seen only in fairly active displays. The effect is indescribable especially if the entire sky is filled with aurorae. People often think they hear sounds or music during such a spectacle, but you can't record it. Even if there really is no sound, there certainly ought to be.

The crowning effect — literally — is the *zenith corona* (such as the one pictured on the cover of the June 1975 issue of ASTRONOMY). Many long rays may appear to converge overhead in a ring or crown. Usually the corona is limited to the rarer active aurorae, but occasionally a normal, quiet auroral display culminates in a short-lived corona.

How often can you expect to see an aurora? If you live around the Great Lakes, you may see a display on the average of 10 to 20 nights per year if you look, but only once or twice if you wait for it "to hit you on the head". In an area starting in Oregon, extending through Nebraska and Indiana



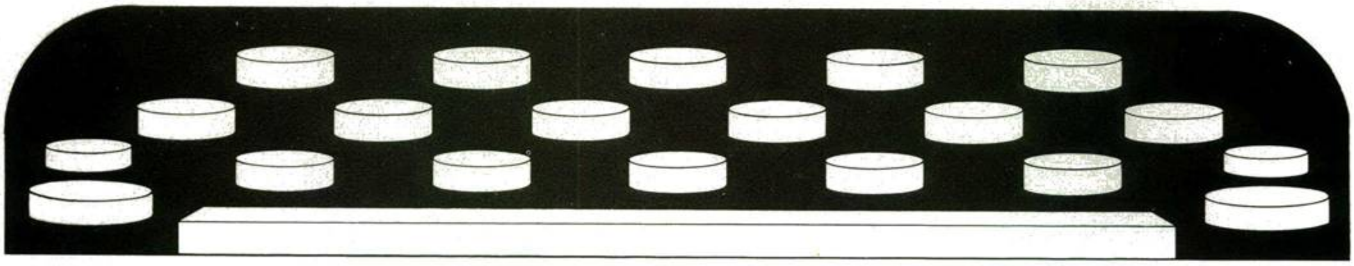
Picket fence aurorae are very strange looking phenomena when they appear in the sky: The number of spikes may vary from two or three to several dozen, and they may fade on and off in a matter of seconds. The rayed band is the appearance most people associate with aurorae, but it's only one of a large number of forms. If the rays extend higher into the sky, the aurora will look like a giant celestial drapery. Artwork by Mark Paternostro.

to Maryland, they are visible perhaps three to five times per year. On the Canadian prairies, northern Ontario and Quebec, you'll see aurorae as often as one night in three, although bigger and more impressive displays will occur less frequently. And those who live in Florida, Texas and California may see some aurorae on the average of once a year — far less often if they don't actively look for it.

Looking for aurorae isn't difficult: When you go out to observe or set-up your telescope, scan the northern part of the sky for unusual brightening or faint greenish color. Mercury vapor streetlights appear greenish, and their glow photographs green on most color films — so don't be fooled by them. If there's a town or city to the north of you, the glow won't be an aurora either. But an unusual glow may be an aurora. Check again a half hour or an hour later. If the glow has grown, it may be an aurora; if it is gone, it might have been one. In either case, look again later on. The identifying characteristic of faint aurorae is that they change. In a typical "little" auroral display, the faint diffuse glow you saw just may have developed by 11 or 12 p.m. into a homogenous arc lying just above the trees; in another hour, it could develop rays and then transform into a band, perhaps with slow movement and weak pulsations. Around 2 a.m., the display may culminate with rays pulsating and reaching toward zenith for 10 minutes or a half hour, and then subsiding until only a diffuse ground aurora remains.

In a more active display, the pace is quicker. By 10 p.m. the display may be a homogenous arc slowly rising and growing brighter, soon developing rays that reach the zenith from time to time. By midnight, the first corona — a weak one — has formed and dissipated; by 1 a.m. several more surges of activity have culminated in coronae and then receded. Some flaming, pulsating surfaces and draperies have formed in the north and northeast. Finally, the aurora breaks up and recedes into the north. By 3 a.m., it is a rayed arc, low in the north, fluctuating slightly in brightness and sometimes sending a ray as high as the pole star.

Needless to say, other nights are less active. An auroral glow in the north may never become bright or active enough to identify as an aurora, or it may surge and reach a brief maximum while you have a coffee break. But if you keep an eye on the north when you observe, you'll certainly see more aurorae and will appreciate the really big displays even more when they do occur.



IN FOCUS

Sir / The article "Finding Unseen Worlds" (April 1976), states that "Barnard's star is the only one around which astrometrists seriously suspect that planets revolve." The article goes on to state that other nearby stars that seemed to show "wobble" actually have no planets.

This seems to be in direct contradiction to previous ASTRONOMY articles. For example, in May 1975, an article entitled "The Search for Intelligence" actually included a table called "Stars With Dark Companions".

Have astrometrists — or ASTRONOMY — changed their minds? Are there planets around other stars or not?

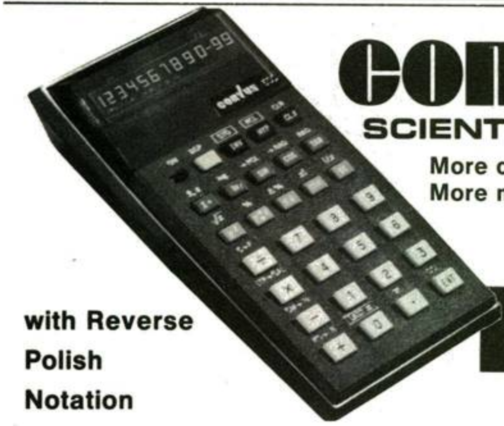
CAROLE SAGE
Pasadena, Calif.

Ms. Sage / Like all sciences, astronomy and astrometry depend on new and constantly changing theories in order to evolve and advance. For example, our current cosmological views are a direct outgrowth of the theories originally advanced by Shapley and Hubble early in this century. On the other hand, some theories do not survive the test of time; new information — and new methods of obtaining it — become available and put certain theories to rest.

Accordingly, theories are made to be tested, and the best "educated guesses" proposed by scientists are intended to be no more than that. But when a new idea happens to strike a responsive chord in our imaginations, we tend to forget this and eagerly acclaim a theory as fact — even before it is proven or disproven.

This is what happened with the "planets" that were thought to circle distant stars. The theory of dark companions was only one way of accounting for certain anomalies in the observation of these stars. But man's romantic eagerness to discover that we are not alone in the universe hit upon this theory as an ideal answer to the quest, and it was proclaimed as factually proven long before more accurate observations were obtained. "Finding Unseen Worlds" was a report of the latest astrometric techniques, which tend to disqualify the previous observations through the use of much more exact — and exacting — measurements.

ASTRONOMY did not intend to say that there are no planets around distant stars — only that they have not yet been definitely detected. Scientists may or may not be able to do so in the near future, depending on advances in instrumentation. Until techniques improve to the point where definitive statements can be made, it would be wise to exercise caution before deciding that a theory is a fact.



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A few of the dozens of persons who have flown into space may be remembered by the general public: John Glenn was first American in orbit; Ed White was first American to walk in space, and Neil Armstrong was first human on the moon. But can anyone remember the second American in orbit, the second American to walk in space, or the second space crew to land on the moon? If you wanted to find out, where would you look for this information?

More than 120 Americans and Russians have been involved in manned space programs, and 80 have flown into space. To keep the record straight, the United States Congress asked the Library of Congress Research Service to prepare a guide to the manned space efforts of the past 15 years. This compendium of biographies, photographs, statistics and flight assignments is the result.

As in any general reference work, it is not for casual reading. Yet the text accompanying each section is often full of intriguing and little-known facts. The U.S. Air Force had two manned space programs of its own in the 1960s (the X-20 and the Manned Orbiting Laboratory), but both were canceled for budgetary reasons. Thirty American spacemen are now engaged full-time in various aspects of the future Space Shuttle project, and the booklet gives their specific duties. A dozen pilots have flown the X-15 rocket plane into space and received international recognition as "astronauts". Many Russian spacemen may have died secretly in training, but only the ones killed in flight were publicly announced and mourned (widespread rumors to the contrary). Several men (all Americans) have actually made four different space flights over a 10 year period.

The tables of actual manned flights are the most complete and accurate ones ever published; Russian names are even spelled correctly!

The answers to the quiz in the first paragraph are Carpenter, Cernan, Conrad and Bean. Answers to nearly any other factual questions about astronauts and cosmonauts can also be found in this valuable reference guide. *James E. Oberg.*

* * *

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Astronautics and Aeronautics, 1972: A Chronology of Science, Technology and Policy

580 pages, paperback, $4.85*
Scientific and Technical Information Office, NASA (1974)

A characteristic activity of dedicated astronomy and space buffs is the keeping of a scrapbook. Information in newspapers and magazines will not appear in books for several years, so the scrapbooks serve as indispensable reference sources. Furthermore, the collection of clippings can be a sign of enthusiasm and interest even if the articles are rarely looked at again.

This type of activity is the core for another NASA/Library of Congress service. Practically all the published literature on astronautics, aeronautics, space sciences and related fields is reviewed, abstracted, and compiled in a special publication. The mass of material is then thoroughly indexed for ready reference (this valuable feature fills about 1/5 of the book and greatly increases its utility). Complete tables of the year's space activities are then attached as appendices.

The list of publications reviewed by the Library of Congress is impressive. In addition to all national news wire services and most major newspapers and magazines, foreign press and radio reports are also monitored. Technical journals are reviewed along with weekly tabloids. Very little escapes the collection.

The only problem is one of timeliness. This book has been issued annually since 1961 (with a special 1915-1960 summary volume), and usually takes 12 to 18 months to prepare. But as the prices rose, so did the waiting time; the 1972 volume took two years to get out, and the 1973 edition is not yet available. Obviously, this service cannot be used to keep up with current events!

Who will use the service? Who needs such a book? At first glance, it would seem useful only as a research sourcebook for writers and historians; in that role, it probably is very appropriate for inclusion in a school library. But, however difficult this may be to believe, the book can also be read as well as referenced! If you start looking up one subject or another, you'll tend to rove through the indexes, the page entries, the illustrations and tables. It is the ultimate scrapbook!

For example, the 1972 edition is full of summaries of editorials and comments on the end of the Apollo moon flights. Preparations for Skylab and Apollo/Soyuz are included. Space astronomy has dozens of citations (each may be only a few sentences or half a page). Many details on foreign space activities which are not even mentioned in the United States are described directly from overseas news sources.

The result is an important space reference book that is more than a mere catalog of events. It is another fine government service which space science enthusiasts can make good use of — if they have the patience to wait! *James E. Oberg.*

* * *

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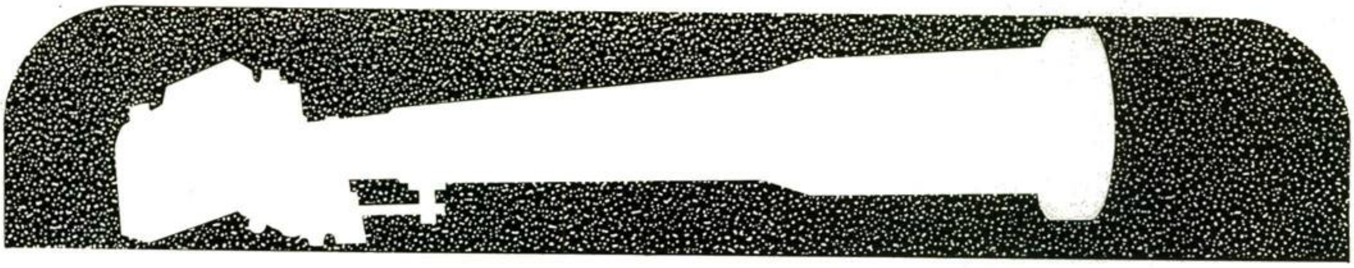


PHOTOGRAPHY IN ASTRONOMY

City Astrophotography

by
Richard Berry

If you live in the city, you may have despaired of ever taking your own successful astrophotos because of smog and light pollution. But don't give up too easily: Even the most light-polluted city environment provides some opportunity for astrophotography. In general, though your choice of subjects is more limited than that of a rural observer gifted with black night skies, clear air and no streetlight glare, every area of astrophotography is still open to you.

Your best bet, of course, is to specialize in the relatively bright objects (the sun, moon, and planets); subjects that require short exposure times, such as constellations, planetary groupings and bright comets, and the very brightest of deep sky objects such as star clusters and the brightest nebulae. In any event, you should also try to *use* the city as long as you're stuck with it. Astronomical objects can gain added interest when seen against the manmade skyline of the city, and hazy city atmosphere makes some types of atmospheric effects — such as strongly orange or red sunsets and moonsets — more common. Don't fight the disadvantages: Use them!

Bright Objects

The moon, sun and planets can "pose" for their portraits equally well in city or country. Surface brightness — the amount of light coming from some unit area of sky — is what counts, and all these objects excel in surface brightness.

For whole disk lunar photography, you can use your camera either at the main focus of the telescope or afocally; in either case, only minor precautions are necessary. Make sure you aren't in the strong glare of lights which might sneak into the film, and be sure your camera coupling is completely light proof. In either case, you may be able to try more low-sky pictures — perhaps with buildings, smoke plumes, city horizons, or (for coastal cities) lighthouses and breakwaters improving the composition. Such pictorial efforts abound in photo magazines, but the astrophotographer will have a head start with equipment.

For close-up lunar photos and detailed planetary shots, the city won't degrade your results at all. In fact, under some meteorological conditions (such as thermal inversions) city air is very stable — an ideal condition for lunar or planetary photography. If you're able to work from the roof of a tall apartment building, you may also obtain the benefit of very great atmospheric stability (if you don't lose the advantage because of building vibrations).

Light pollution is no problem in photographing the sun. The city permits increased opportunities to include manmade objects, as well as more red suns setting over picturesque railway yards and the like; whether it is considered astrophotography is another question. Daytime seeing conditions, however, are markedly inferior because heated air rises from paved surfaces and is stirred into the atmosphere around tall buildings. But a great deal of fine solar photography has been done in and around large cities, so give it a try.

Short Exposure Subjects

Many of the brighter objects in the sky — especially the naked eye planetary groupings, constellations, and objects like bright comets — can be photographed as effectively under city conditions as

Above: The moon and Venus form a striking and brilliant pair over Topeka, Kansas. A medium telephoto lens was used for an exposure of several seconds on Kodachrome II film. Photograph by Rick Schmidt. Below: Just one evening earlier, the crescent moon had hung over this suburban front yard in Dallas, Tex. Despite streetlights, the picture conveys the pleasure of watching the sky on a "soft" May evening. Photograph by John Sikora.

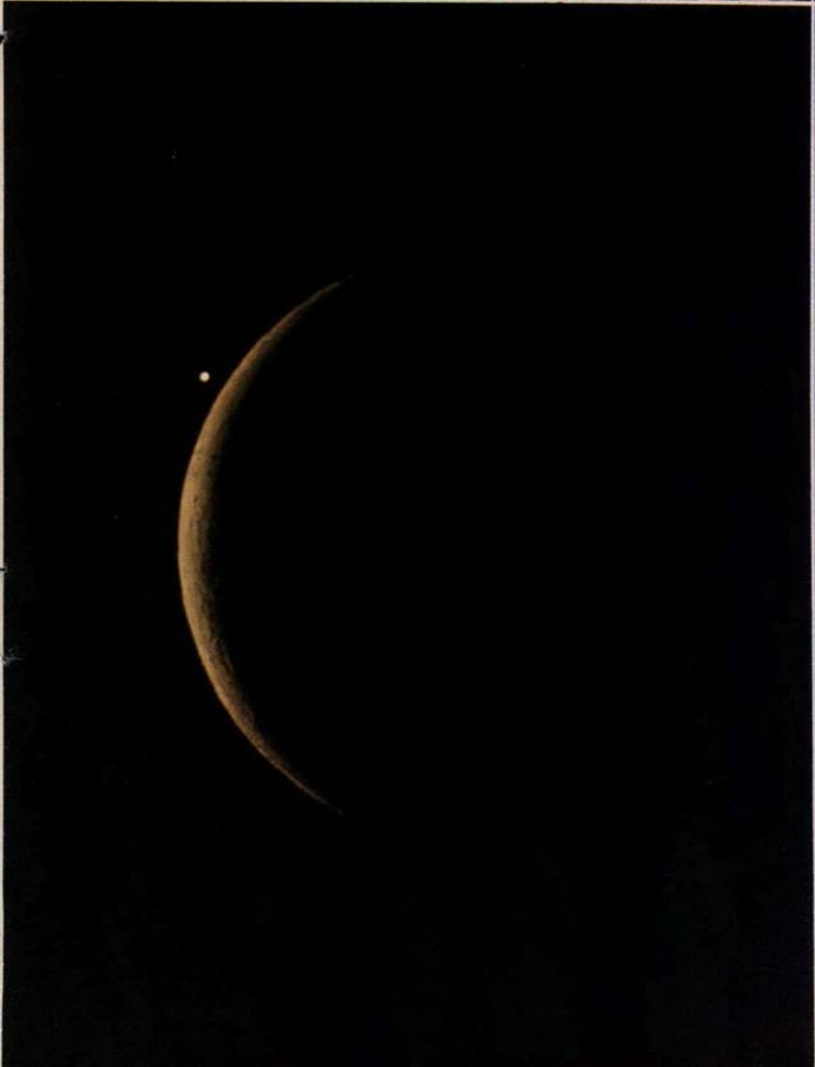
Top left: Above Chilton, Wisc., the constellation Canis Major shines in a 15 second exposure on GAF 500. Photograph by Daniel Koehler. Lower left: Over Huntsburg, Ohio, Auriga was recorded in a 20 second exposure at f/1.8 on High Speed Ektachrome. Photograph by Wolfram Kiparski. Above: A three minute exposure over suburban Alexandria, Ind. shows far more stars in Orion than the eye can see. Photograph by James Kerr. Opposite, top left: The moon, photographed with an eight inch Schmidt-Cassegrain, could have been photographed anywhere. Photograph by Steve Reed. Opposite, top right: Jupiter shows subtle markings in this shot taken with a 16 inch Cassegrain reflector. Photograph by Charles Capen. Opposite, center right: Mars shows astonishing detail in a 1/2 second exposure on High Speed Ektachrome, taken with an eight inch reflector at f/80. Photograph by Steve Reed. Opposite, lower left and right: With an eight inch f/6.5 reflector, photographs of the July 1974 occultation of Venus were made before and after sunrise. Exposures were 1/15 and 1/60 second on High Speed Ektachrome. Photographs by Fred Espanek.

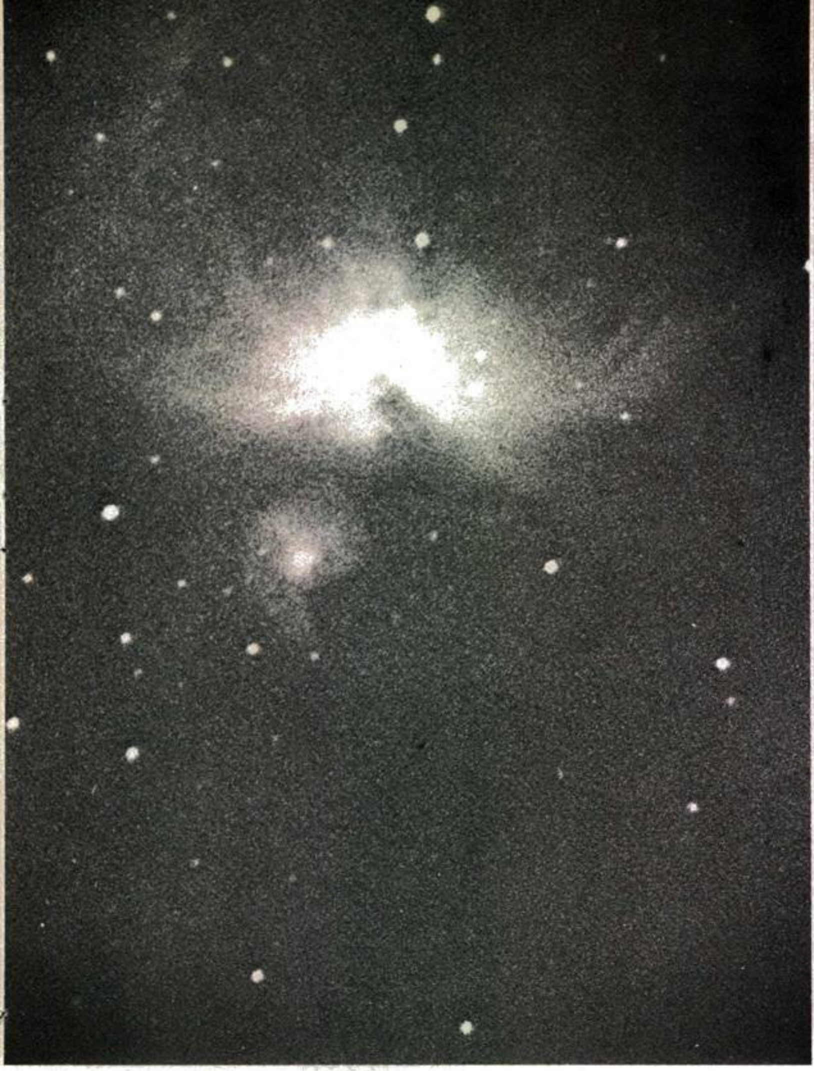
they can anywhere. A normal camera lens (or sometimes a medium telephoto) is best for planetary groupings. Use a moderately fast film, wide lens openings, and exposures of a few seconds for twilight configurations. The city foreground can become a definite "plus" feature: Streetlights or other annoyances can be used to add interest and define an otherwise dull horizon. Weird effects such as streetlighted foreground trees can sometimes add strong areas of color. Familiar city landmarks — Milwaukee's breweries, St. Louis' arch, the Manhattan skyline, the Golden Gate bridge — in the foreground of conjunction or lunar eclipse pictures will add interest far beyond the realm of astronomy.

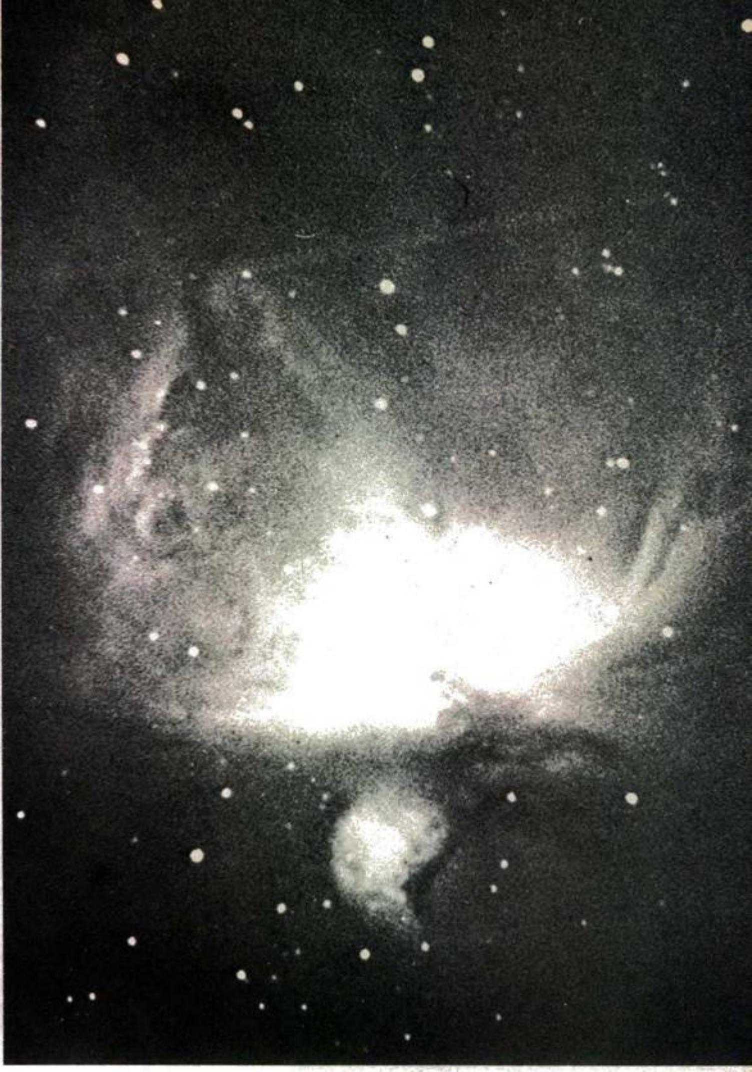
Many pictures of comet West received at ASTRONOMY showed cityscapes with city lights shining in the valley below, transmission towers, smokestacks, or tall buildings. Suburban settings are perhaps the least interesting for buildings, but the suburbs usually offer a variety of trees which, if artfully employed, can create a pleasing foreground. The secret is to plan your pictures beforehand, and then take the photograph at the appropriate time.

Unlike planetary groupings, constellation photography usually does not include the horizon. Since light pollution tends to color the sky green or yellow (both esthetically unacceptable sky colors), exposures should be kept short so that the sky remains black. Fixed camera photography is thus perfectly suited for constellations. Simply place your camera on a tripod, open the lens wide and frame the constellation you wish to record, and make an esposure of 10 seconds. With the fastest films available, 10 seconds may be too long; you may obtain more pleasing results with slower and less grainy films.

Lunar eclipses are almost traditionally photographed over cities. The eclipsed moon seldom becomes so faint that light pollution is a problem, and the city can add drama and uniqueness to the picture. Exercise care in selecting your foreground: It must be chosen to add rather than detract from the picture.







Opposite top: A six inch reflector with a full aperture filter was used to take this photograph of the sun's surface on Kodachrome-X at 1/500 second exposure. Photograph by Steven Wheatcraft. Opposite, lower left: Above Charleston, W. Va. on the morning of March 7, 1976, comet West was captured in a 30 second exposure at f/2.8 on High Speed Ektachrome. Photograph by Chris Callahan. Opposite, lower right: In 1974, a brilliant display of aurorae over Sheboygan Falls, Wisc. was recorded in a 10 second exposure. Photograph by Mike Kuehn. Above left: With an eight inch telescope at f/5, this exposure of the Orion nebula was stopped by sky fog in just five minutes on 103aF film. Above right: Use of a red filter to cut light pollution enabled an extended exposure of 30 minutes, recording far more detail. The shot was taken from Manhasset, N.Y. Photographs by David Healy.

Deep Sky Photography

Strictly speaking, deep sky photography is impossible in the city. But you *can* successfully record some of the brighter nebulae even against very bright skies, and objects such as star clusters can be photographed astonishingly well. The nebulae bright enough can be counted on your fingers: the Orion nebula, M-27, M-57, M-31, and perhaps a few others — admittedly a rather paltry list. Using a red filter to eliminate some light pollution will work well for the Orion nebula (see "Red Light Sky Photography", ASTRONOMY, August 1976), but planetary nebulae and M-31 do not emit strongly in H-alpha and the red filter technique will not greatly improve the results. You'll achieve optimum results with telescopes of long focal length giving a large image, and fairly high f-ratio: Even an f/15 refractor becomes a "deep sky" instrument in city sky conditions.

Black and white film should be high contrast and fine grained film such as SO-410; be prepared to print on very high contrast paper. Color photography will be badly limited by the background; unlike black and white, the color cannot be eliminated and the contrast cannot be easily raised. Thus, you should simply try to underexpose the sky to keep it dark.

Star clusters are particularly suitable for city astrophotography. Long focal length and slow f-ratios do not generally affect the recording of stars adversely, though the sky will be dimmed. You may also want to try photographing double stars using the same technique normally employed with high resolution planet photography — a type of photography that very few observers have tried — to pit your skill against the atmosphere. Exposures of a few seconds will show stars down to sixth magnitude even at f/80 with an eight inch telescope.

Astrophotography is more difficult in the city, but certainly not impossible. If you use the city as foreground and don't try to take on the impossible job of getting the faintest nebulae against a city sky, you'll still find plenty of satisfaction as a city astrophotographer.

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- **Ability to choose, specify and/or assign photographs, diagrams, charts, tables, maps, paintings and artwork to illustrate articles in ASTRONOMY as well as coordinate and implement complete issue layout.**
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ASTRO-NEWS

Latest News From the World of Astronomy

Skylab Revisit Planned

NASA is considering proposals to send a new crew of astronauts to the derelict Skylab space station. The 100 ton space outpost has been empty since the return of the last crew 2-1/2 years ago.

Plans are being formulated for a visit to the space station during an early test flight of the space shuttle rocket plane. The reusable shuttle will form the backbone of America's space efforts for the rest of the century. Drop tests will begin in mid-1977, and orbital space flights are scheduled for 1979.

The actual development schedules could present a problem for the Skylab revisit, which is one reason that definite plans cannot yet be made. In its present orbit, Skylab is slowly decaying toward the atmosphere where it will burn up in late 1980 or early 1981. Yet a space shuttle visit cannot be executed until early 1980, with possible technical problems in the program causing a delay of a year or more. The schedule, therefore, is very tight.

Several purposes have been proposed for the rendezvous of the new space shuttle and the old Skylab. Astronauts would inspect the space station, retrieve samples of materials left behind by the last crew in case a new visit is ever made, and examine the long-term survival of construction materials.

A major concern to NASA officials is the eventual re-entry of Skylab into Earth's atmosphere. The satellite is so large and consists of such bulky pieces that much of it is bound to reach Earth. These falling objects — such as film vaults, tanks, 1,000 pound gyroscope wheels, the telescope mount and other items — could cause widespread damage, injury, and even death if they hit Earth in a populated region. During the random re-entry of Skylab's Saturn booster last year, officials waited in tense expectation as its final orbit carried it across a half dozen large cities in Europe and the Middle East. Fortunately, the S-II rocket went down over an ocean.

A deliberate "de-orbit" maneuver would be the very least which NASA would like to see done with Skylab. Unfortunately, the space shuttle has neither a strong docking collar nor rocket engines in the correct orientation to carry out the "push" itself. Even if it did, space planners would be concerned that pieces of Skylab would shake loose during the maneuver and impact the delicate thermal protective coating on the space plane.

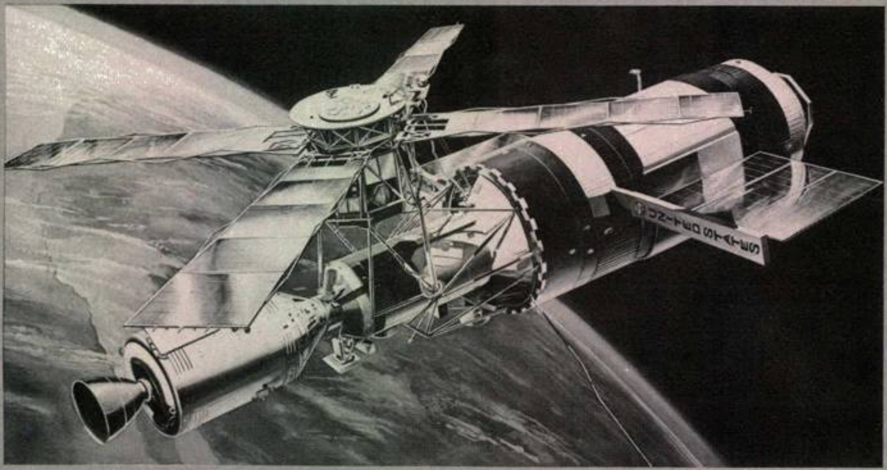
Consequently, the feasible alternative is to attach a rocket unit to the Skylab. The space shuttle could fire the rocket by remote control in the appropriate direction for a controlled descent into the atmosphere over some uninhabited and untraveled area on Earth.

With the rocket engine installed, however, the astronauts will have an entirely different opportunity which is beginning to excite space officials. Skylab could be boosted back into a higher orbit where it would be safe from burning up for another 10 years or more. During this time, NASA might decide to proceed with the controlled destruction of the vehicle. Or, if the systems test out on the first visit, the space agency may attempt to reinhabit the Skylab for long space flights.

Many engineers close to the Skylab project are extremely skeptical that it would be possible to regain a shirtsleeve environment inside the space station. When it was abandoned in February 1974, the power systems were irretrievably turned off. Both the storage batteries and the stabilization systems were nearly useless. Crew consumables such as food were totally exhausted.

But these problems may be solvable, and this is what NASA's current study project is attempting to answer. Perhaps a new set of batteries could be installed in the rocket section to be attached to Skylab by the space shuttle. Perhaps an entirely new stabilization system could be included. New food could be brought up (the Skylab still carries ample supplies of water and oxygen).

SKYLAB *continued on page 58*



Skylab is pictured as it circles Earth at an average altitude of 235 nautical miles. An astronaut services the Apollo Telescope Mount. Photograph by Martin Marietta Corporation.

Sunspots Indicate Solar Variability

Evidence continues to mount that our sun is not a steady source of energy. Astronomer John Eddy, of the High Altitude Observatory in Colorado, has revived the theory that solar variations over the past millennium can account for climatic and other changes on Earth (see Astro-News, ASTRONOMY, May 1976). This revival has been followed by the announcement that a group of radio astronomers in Canada have detected a new kind of solar radio variability, associated with the x-ray bright points first studied in detail from Skylab.

Reporting the observations to astronomers at the University of Sussex in England, Paul Feldman, of the Herzberg Institute of Astrophysics in Ottawa, described the search for 9.4cm radio emission from flaring solar x-ray bright points, made with the 46 meter radio telescope at Algonquin. From 52 hours of data there is clear evidence of radio emission associated with one flaring x-ray event; peaking at about 1,200 Jansky, this radio flare is by far the weakest ever recorded from the sun, for which radio events are usually measured in multiples of the *solar flux unit* (10,000 Jansky). Unequivocal confirmation of the association of the radio flare with a flaring of an x-ray bright point comes from simultaneous observations made by detectors on board NASA's Orbiting Solar Observatory-8, and communicated to Algonquin by C.J. Wolfson of the Palo Alto Research Laboratory in California.

These x-ray bright points on the sun have been of particular interest to solar physicists since the Skylab observations showed that as many as 1,500 of these small, active regions emerge on the sun's surface each day, live for a few hours, and then die away. From the Skylab statistics, the Canadian team expected that their antenna system would be able to detect as many as six of the associated radio outbursts in a two day period. The fact that only one was observed in 52 hours hints that there are fewer of these outbursts at solar minimum (the observation was made on June 9, 1976) than when the sun was more active. All the observations of these bright points on which the statistics are based have been made since their discovery in 1969, around the time of the most recent solar maximum.

In addition to being an observational triumph in refining the radio study of the sun, this work provides new evidence of solar variability. It is increasingly clear that the pattern of sunspot variations is the most obvious feature of a much more intricate and subtle pattern of variability. The magnetic flux brought to the surface of the sun by thousands of these small active regions in a month is probably more significant, in terms of the overall variability of the sun, than the proportion affected by a few large spots. This is likely to point the way to an understanding of some of the sun-Earth correlations found by Eddy and others.

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SKYLAB

continued from page 57

Clearly the effort to repair the Skylab would be difficult. It would involve extensive extravehicular activity, or space walks, on the part of astronaut crews. Many systems which must be relied upon were never built to survive for longer than one year in space.

Offsetting these problems are two potential benefits. First, Skylab would be a powerhouse in orbit, feeding valuable electricity to the space shuttle for flights much longer than those possible on shuttle power supplies alone. (The shuttle uses limited fuel cells instead of solar panels for electricity.) Second, the Skylab has a battery of powerful scientific instruments possibly still ready for further use; a prime example is the Apollo Telescope Mount.

The rebuilt Skylab could also serve as the next setting for a new joint Russian-American space mission. If the attached rocket module were equipped with the universal docking system designed for Apollo/Soyuz, Soviet cosmonauts in Soyuz or more advanced spacecraft could visit their American colleagues in orbit.

The "Skylab return" project, if it proves workable (and there are too many unknowns at the present time to make any final decisions), could have psychological benefits as well. The reuse of already-paid-for equipment would be attractive from an economy standpoint. From the "rescue" point of view, it could capture the imagination of the world, injecting a sense of urgency into the space shuttle flight schedule. It would be a quick and adequate response to the overwhelming Soviet space station effort of the late 1970's.

NASA's current plans for space science, including astronomy, foresee a combination of unmanned robot stations and manned Spacelab modules which remain attached to space shuttle vehicles on flights of 6 to 30 days duration. A "free-flying" space station is only under preliminary study, and would not be available for flight until the mid-1980's.

The revitalized Skylab is seen as a potential bridge across this capability gap. Manned flights could be extended to four to six months in length. Large manned astronomical installations could complement the long-lived Space Telescope (unmanned) and the brief but intense SUOT (Shuttle Ultraviolet/Optical Telescope).

Beyond these scientific programs, Skylab could become a factory in orbit where new space processing techniques are carried out with the power generated by the solar panels. Experiments in large-scale power generation and in space-to-space and space-to-ground power transmission must be made before the large space power stations can be built. Such stations could forever free the United States from the need to either import foreign energy or destroy the domestic environment for local fossil energy supplies.

Theory Proposes Meteorite Origin In Asteroid Belt

Meteorites originated within our solar system (not deep space), possibly in the asteroid belt, according to evidence gathered by Australian metallurgist Dr. Richard Jago.

Jago bases his claim on an experiment in which an iron meteorite section was cut, polished, and subjected to extreme cold. [The reasoning behind the extreme cold is that in the outer regions of space, temperatures drop to -452 degrees Fahrenheit (-269 degrees Centigrade) — four degrees above absolute zero, the point where even the movement of atoms ceases. Temperatures within our solar system are much warmer, from the intense heat of the sun to about -148 degrees Fahrenheit (-100 degrees Centigrade) at the outer limits.]

By immersing the piece of iron meteorite in liquid nitrogen, Jago brought the temperature down to -320 degrees Fahrenheit — not as low as in outer space, but lower than any conditions inside the solar system. "The fact that this caused a change in the meteorite metal indicates that it was never before subjected to cold more extreme than that found within the solar system," he said.

Jago believes the asteroid belt is the primary source of meteorites, because pieces of the debris frequently collide and are knocked into a concentric orbit that puts them on an inevitable collision course with Earth.

"While the theory is still unproven, the result of the experiments seems to confirm that the search for the origin of meteorites can now at least be narrowed down to the solar system," Jago said. He added that the results must be viewed with scientific caution until confirmed by similar freezing tests on more meteorite samples.

Construction Continues On VLA Radio Telescope

The world's largest radio telescope is spreading its Y-shaped appendages of antennas, railroad tracks and electronic nerves along 13 mile (21km) legs on the Plains of San Augustin.

Named the Very Large Array (VLA), the telescope will consist of 27 disk antennas, each 82 feet (25m) wide and weighing 160 tons. When completed in 1981, the VLA will have the power and sensitivity of a single, conventional dish radio telescope — such as England's Jodrell Bank — that would circle more of the nation's capital than the Capital Beltway.

The $76 million cost seems minute when compared to other existing programs. The VLA's purpose will be the study of extragalactic space — beyond the Milky Way. It will probe quasi-stellar sources (quasars) which have been spotted racing away at more than half the speed of light [over 93,000 miles (150,000km) per second]. The most skittish known quasar is estimated to be six trillion light-years away, traveling at 90 percent the speed of light.

Runaway quasars and other phenomena such as black holes, star formation, structure of galaxies and interstellar molecules are expected to be the main targets of astronomers when the Array is completed.

The VLA will correct three basic gaps in the state of the art: poor resolution, poor sensitivity and the time lag involved in making images or maps.

Signals from the 27 dish antennas will be routed through underground wave guides to a control center as the "Y" system is rotated. The signals will be amplified and fed into a computer system which will turn out high resolution "pictures" of the radio source in 8 to 12 hours.

Robert E. Dorr, business manager for National Radio Astronomy Observatory at Socorro, N.M., said two of the 27 dishes are complete, have been undergoing trials, and have received radio signals from space.

Dorr said public facilities for the VLA probably will include exhibits of educational interest along a walking path with push-button, taped explanations. A gallery is planned for the control center where visitors may view operations.

Does the Sun Really Generate Its Energy Thru Nuclear Fusion?

For years, astronomers have held a solid belief that the sun generates its energy through nuclear fusion — specifically, via the proton-proton cycle (the same reaction which powers the hydrogen bomb). Supposedly this concept was solidly grounded in nuclear physics and our knowledge of stellar interiors. Recently, however, Raymond Davis and his collaborators have begun to study this solar model with considerable critical scrutiny.

Davis has been trying to detect elusive neutrino "particles" resulting from the proton-proton cycle, but has thus far been unsuccessful. His method depends on observing the argon atoms resulting from the capture of solar neutrinos by atoms of chlorine. This process is called "inverse beta decay", and the chlorine-argon reaction is sensitive only to high energy neutrinos in the range of 5 to 10 million electron volts (MeV). Unfortunately, calculating the flux of high energy neutrinos is critically dependent on models of the solar interior which, until now, were thought to be well understood. This is a worrisome and potentially fatal flaw with which the Davis experiment must cope.

Now, a potentially better test has been proposed by R.S. Raghavan of Bell Laboratories. In a recent edition of **Physical Review Letters**, Raghavan noted that the element indium (^{115}In) transmutes via neutrino capture to an excited state of tin at an energy of only 0.614 MeV. Hence, the reaction would be sensitive to the low energy neutrinos of the proton-proton cycle whose flux is less model-dependent than in the chlorine-argon case. If so, a more valid experimental test of the proton-proton cycle could be possible.

Difficulties exist, however, with respect to accidental background events since low energy radiation must be detected. Nevertheless, Raghavan noted, the reaction has a unique signature due to an electron emitted upon neutrino capture and two gamma rays at energies of 0.116 MeV and 0.498 MeV, which are emitted by the tin as it decays to its ground state. This offers a good possibility that real events could be readily differentiated from background contamination. If so, a real breakthrough may be achieved in the solar-neutrino problem, and perhaps solve the contradictions in current solar astrophysics.

Stellar Oscillations Lead to New Group of Variable Stars

A new category of variable stars, which may turn out to be the most abundant type of all, has been discovered by astronomer Norman Walker at Granada University Observatory in southern Spain.

The star flickers erratically by a few hundredths of a magnitude, roughly every 40 to 60 minutes. One explanation being discussed is that the variations are caused by slight oscillations of the stars' outer layers, like those recently reported for the sun.

The erratic fluctuations were found in about 20 hot, bright stars of spectral types B and A. These stars have surface temperatures ranging from about 8,000 to 30,000 degrees Fahrenheit and are from 2 to 20 times as massive as the sun.

Walker used a sensitive photometer capable of measuring brightness changes 10 times smaller than those actually found. The photometer was coupled to the Granada Observatory's 12 inch telescope.

Walker used the Spanish observatory because its altitude (8,600 feet) gives particularly clear skies for photometry. His intention was to search for possible light fluctuations in a peculiar celestial family known as the Lambda Bootis stars. Instead, his observations revealed that the comparison stars were varying in an erratic and unexpected manner.

Such variations have not been noticed before because of the stars' irregular period and amplitude, unlike the cyclical variations of pulsating stars such as Cepheids. Instrumental and atmospheric effects were ruled out because each star varied in its own way.

Apart from one cool (K type) giant, all the stars Walker examined fluctuated in brightness to some extent. The maximum change was .06 magnitude.

All stars of spectral types A and hotter may show these fluctuations. Because of their high masses, these stars have hotter cores than the sun and produce most of their energy by the carbon cycle of nuclear reactions, rather than the proton-proton chain that occurs in the sun. They also have a different structure, lacking the sun's deep convective outer layer and instead carrying energy to the surface by radiation.

Walker noted that such hot stars have violently active surfaces. The brightness variations may be caused by flares associated with turbulence.

However, an alternative explanation for the variations has been offered by George Isaak of Birmingham University, one of several scientists who recently discovered oscillations of the solar surface. Isaak predicted that similar oscillations to those of the sun exist in the outer layers of other stars. These oscillations would be visible as slight brightness variations. The sun should also show small changes in luminosity if it could be measured against a comparative star.

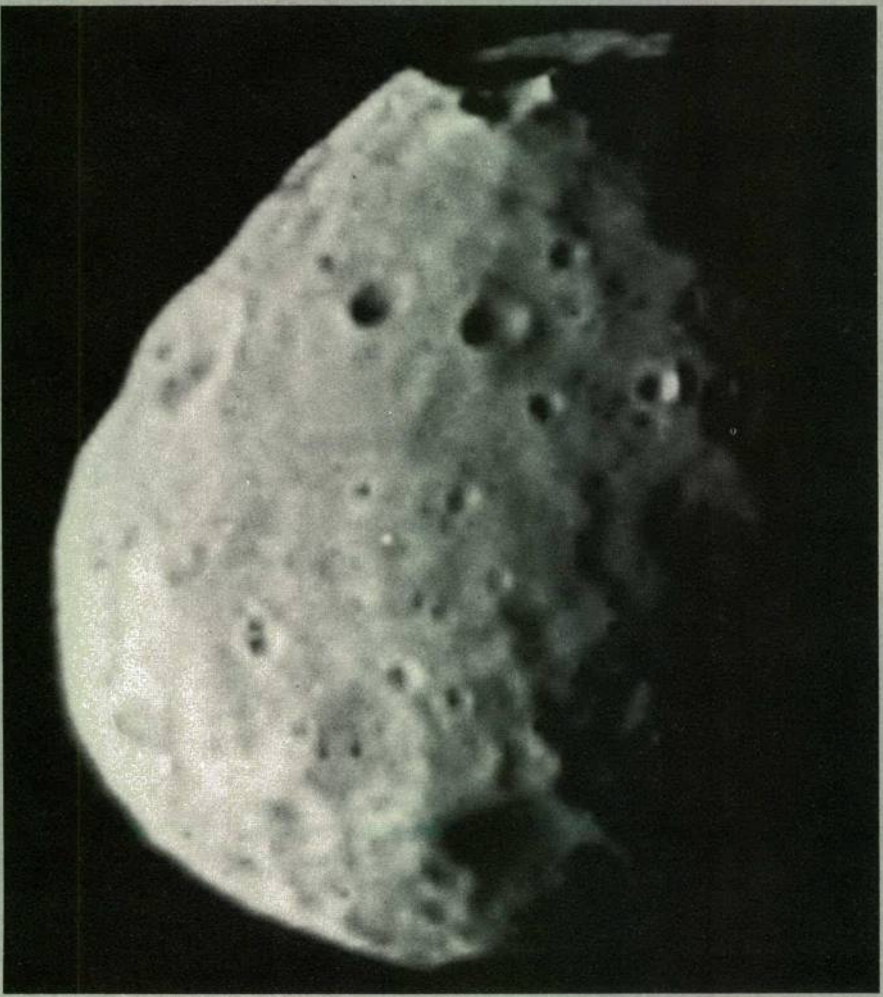
One argument against Isaak's theory is that the amplitude of the stellar variations is 10 to 100 times that expected for the sun. But Isaak replies, "Whatever property the sun has, we find some stars have much more of it."

To settle the matter, the stellar fluctuations must be analyzed for evidence of different periods, which would result from several oscillations beating together like a musical chord.

Whatever their cause, Walker's observations challenge traditional views of stars and, like the missing solar neutrinos, provide an additional headache for theorists.

The observations imply that every star must be assumed variable until proved otherwise.

One observer has suggested that astronomers now must carefully reexamine every star previously believed constant in light output for possible variability.



Phobos is shown in the first photograph of it taken from the Viking 1 Orbiter. Only 1/2 the surface is illuminated, with the total diameter measuring 14 miles (22km). NASA photograph.

Firms Considered for Space Industrialization Proposals

NASA is taking steps to remedy the charge of critics that space exploration is an unproductive waste of the taxpayer's money with a broad concept called "space industrialization".

Two companies — an aerospace firm and a research "think tank" — will be chosen to prepare proposals for future research, development and operational activities to be conducted in space from 1980 to 2010. The industrialization process would begin with the space shuttle/Skylab apparatus, and evolve into facilities for permanent, practical, commercial use of space. Activities would be undertaken for the production of goods and services that would be of economic benefit to the public.

Power generation and manufacturing processes are two potential areas where production in space would be more efficient than on Earth.

Areas that show promise include: the manufacture of materials, chemicals and medicines; development of new materials and processes; new communications industry; weather services; new Earth resources development, and ultimately the movement of people to space for tourism or medical purposes with the eventual industrialization of the moon.

Satellite Orbits Pole

From a polar orbit, the NOAA-5 (National Oceanic and Atmospheric Administration) satellite will provide photographs and other data while it scans Earth's entire surface twice every 24 hours.

The satellite, launched recently by NASA from Vandenberg Air Force Base, is equipped with a scanning radiometer system for both visible and infrared data, with resolution of about two miles in the visible and four miles in infrared.

The very high resolution radiometer system can show features 1/2 mile in size, while the vertical temperature profile radiometer system measures infrared energy at six levels of the atmosphere and at Earth's surface.

The satellite also contains a solar proton monitoring system, which will provide warnings of solar storms which could disturb communications on Earth as well as affecting Earth's magnetic field. The system will provide data on the effect of solar protons on the satellite itself, which will be particularly important for future manned space flights.

Weather conditions and other data provided by the satellite have a variety of uses in addition to weather forecasting. Search time for lost aircraft has been cut drastically by use of satellite weather photographs, according to Col. James P. Bigelow of the Civil Air Patrol. Instead of searches lasting one to two weeks, the patrol can find downed aircraft in 24 to 48 hours, he said. Use of satellite photos for searches began in California, and nationwide use of the system began July 15 of this year. The accurate knowledge of weather conditions provided by satellites, plus knowledge of the aircraft and pilot experience provide the basis for the searchers to make an educated guess as to where an aircraft probably went down, Bigelow added.

Another aircraft related use of satellite photographs is pilot briefings with regard to the weather by Federal Aviation Agency (FAA) flight service stations. By the end of 1976, FAA stations in Los Angeles, Oakland, Miami and Oklahoma City will be using the satellite weather information to brief pilots of light aircraft.

Enhanced infrared data will show temperature variations on the surface of Pacific coastal waters, giving rise to another use for the satellite photos. Such information can be of great value to tuna and salmon fishermen in helping them locate a catch. The satellite photographs also provide valuable information for flood and snow-melt water supply forecasting.

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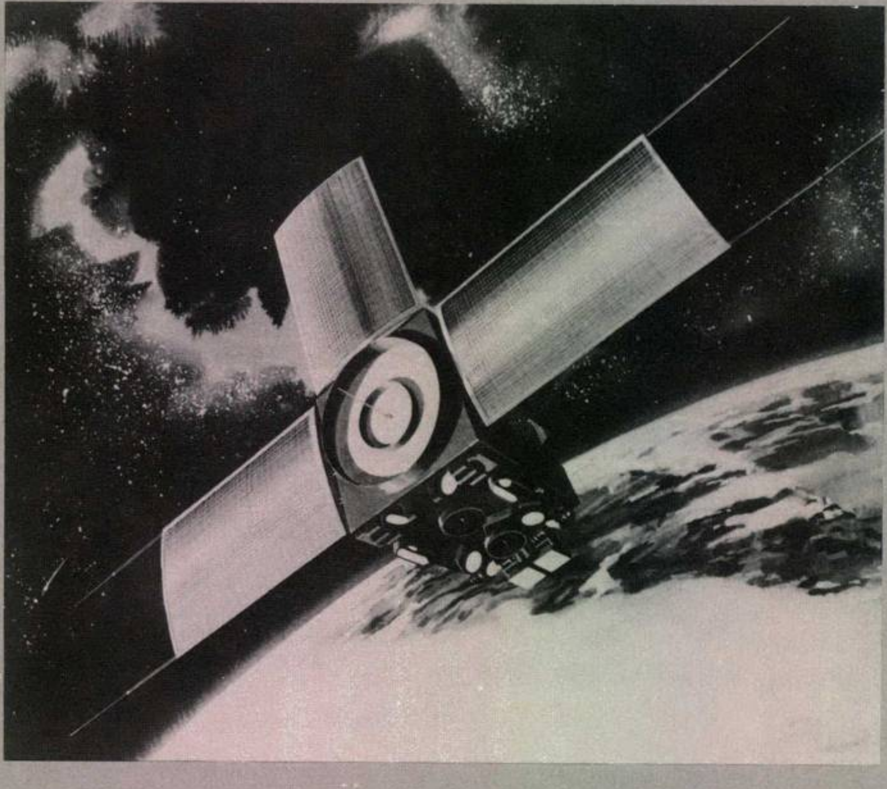

NOAA-5 is depicted in its polar orbit. The satellite is the fifth in a series which began in 1970. NASA artwork.

Masers Used to Study Water Vapor in Stellar Birth Regions

Radio astronomers in the United States, Australia and the USSR have joined forces to put together the world's largest radio telescope. The telescope has the capability of resolving a source less than 2/10,000 second of arc — a figure which can be compared to looking at a man's footprint on the moon.

The telescope is being used to study clouds containing water vapor in regions where new stars are being formed. The water vapor produced readings of intense radio radiation when observed with maser amplification. Instead of using light (as in laser amplification), a maser uses microwaves, which is *m*icrowave *a*mplification by *s*timulated *e*mission of *r*adiation.

This combination of antennas or the Very Long Baseline Interferometry (VLBI) method is used to achieve the highest angular frequencies ever at radio frequencies. Each antenna records the signal on videotape for comparison at a later date. If the recordings match, the source's size can be determined by the superantenna with the precision of a radio telescope that is actually the size of the distance between the two antennas.

The antennas used in the maser experiment were the 85 foot antenna of the Naval Research Laboratory's Maryland Point Observatory; the 130 foot antenna of the California Institute of Technology at Owens Valley; the 210 foot antenna of NASA's Deep Space Network (DSN) at Tidbinbilla, Australia, and the 72 foot antenna of the Soviet Crimean Astrophysical Observatory at Semeiz.

The high angular resolution of the VLBI was necessary to observe detail in the spatial structure of the molecular water vapor clouds in the galaxy. The clouds are extremely luminous, and are believed to be natural masers having temperatures on the order of one hundred trillion degrees.

The most intense of these sources appears to have the same water vapor spectrum as our sun. The only difference is that the source, called W29N, is radiating this energy level from a distance of three billion astronomical units.

Scientists believe that water vapor masers may be associated with the process of star formation. The high resolution of the VLBI allows measurement of the size and shape of individual masers and their distribution within the cloud.

Due to the obscuring cloud, radiation is usually impossible to observe at other frequencies — which is why the masing radiation is so important. It permits scientists to study a star (on a microwave basis) as it is being formed and to analyze the conditions that are necessary for stellar formation.

Signals from two strong water vapor masers, W29N and W51, were recorded on videotape at precisely the same time when they were both above the horizon for approximately one hour. The two antennas used for this recording — at Maryland Point and Tidbinbilla — are spaced pretty close to the maximum distance apart. The maximum spacing achievable is Earth's diameter [7,825 miles (12,600km)], The separation between the two antennas is 7,508 miles (12,091km), which is very close to this limit.

Scientists at each telescope had to use hydrogen maser frequency standards to tune the water masing signal down in frequency in order to record it. These frequency standards derive their stability from a transition of neutral hydrogen atoms at 1,420 MHz, and are the most accurate clocks that man can make. They are correct to about one second in a million years.

The spatial structure of the water molecular masers was found to be very complex. The recorded signals from the masers displayed varying correlations with time over the different baselines of the interferometers. The size of the sources ranged from half to three times an astronomical unit (the distance between Earth and the sun).

The masers appear in clumps in the source W29N, which may be an indication that several stars may have formed at the same time in this cloud. Further analysis of the data received will be needed to make definite conclusions concerning star formation.

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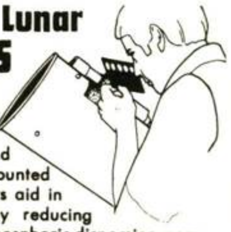

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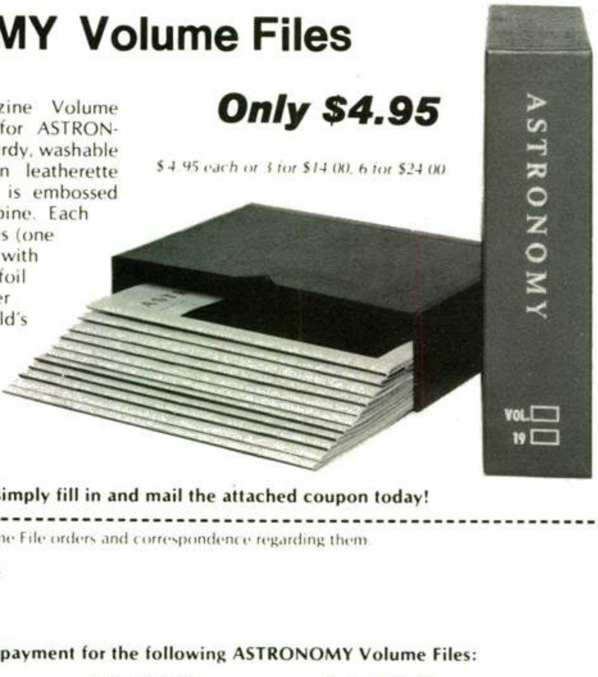

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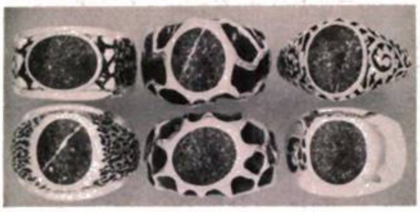

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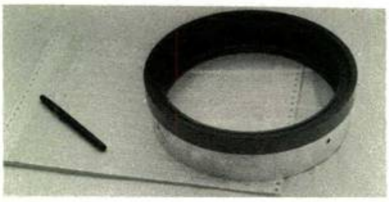

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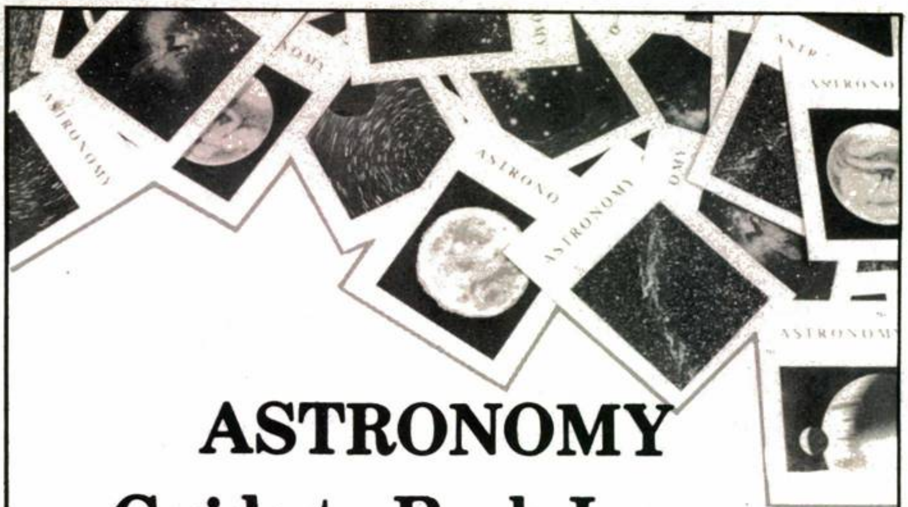
ANNOUNCEMENT — AIAA/FASST present "The Search for Life in Our Solar System"; Oct. 8, 1976, JPL, Pasadena, CA. For college students. Speakers include: Gerald Soffen, James Martin, scientist/astronaut Dr. Karl Henize. For details, write Leonard David, Director, Student Programs, FASST, 1785 Massachusetts Ave. N.W., Washington, D.C. 20036.



ASTRONOMY

Guide to Back Issues

Reader interest in back issues of ASTRONOMY magazine is higher than ever. As a result, our stock of back issues is swiftly dwindling. Below is a guide to ASTRONOMY back issues that are still available. For your convenience it is updated monthly; issues not listed are depleted. **The July 1976 History of American Astronomy issue is specially priced at $3.50 per copy plus postage.**

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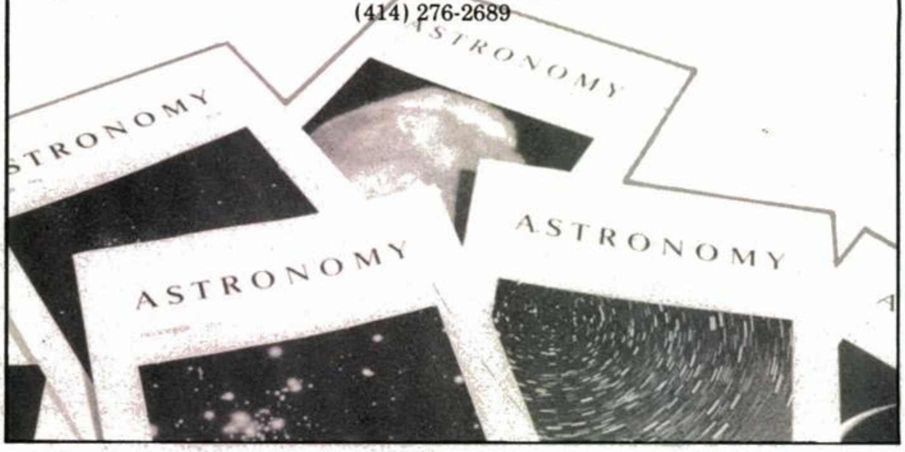
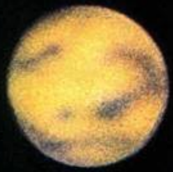


Planet Finder



Ⓒ Ceres

Oct.	1	15
R.A.	10h30m	10h54m
Dec.	+17°00'	+15°14'
Mag.	+8.7	+8.6

Ⓐ Mercury

Oct.	1
R.A.	11h35m
Dec.	+ 2° 56'
Mag.	+0.9

Ⓑ Mercury

Oct.	15
R.A.	12h32m
Dec.	-1°18'
Mag.	-0.8

Ⓜ Mars

Oct.	1	15
R.A.	13h34m	14h10m
Dec.	-9°33'	-13°00'
Mag.	+1.9	+1.8

Ⓝ Neptune

Oct.	15
R.A.	16h42m
Dec.	-20°45'
Mag.	+7.7

SUN

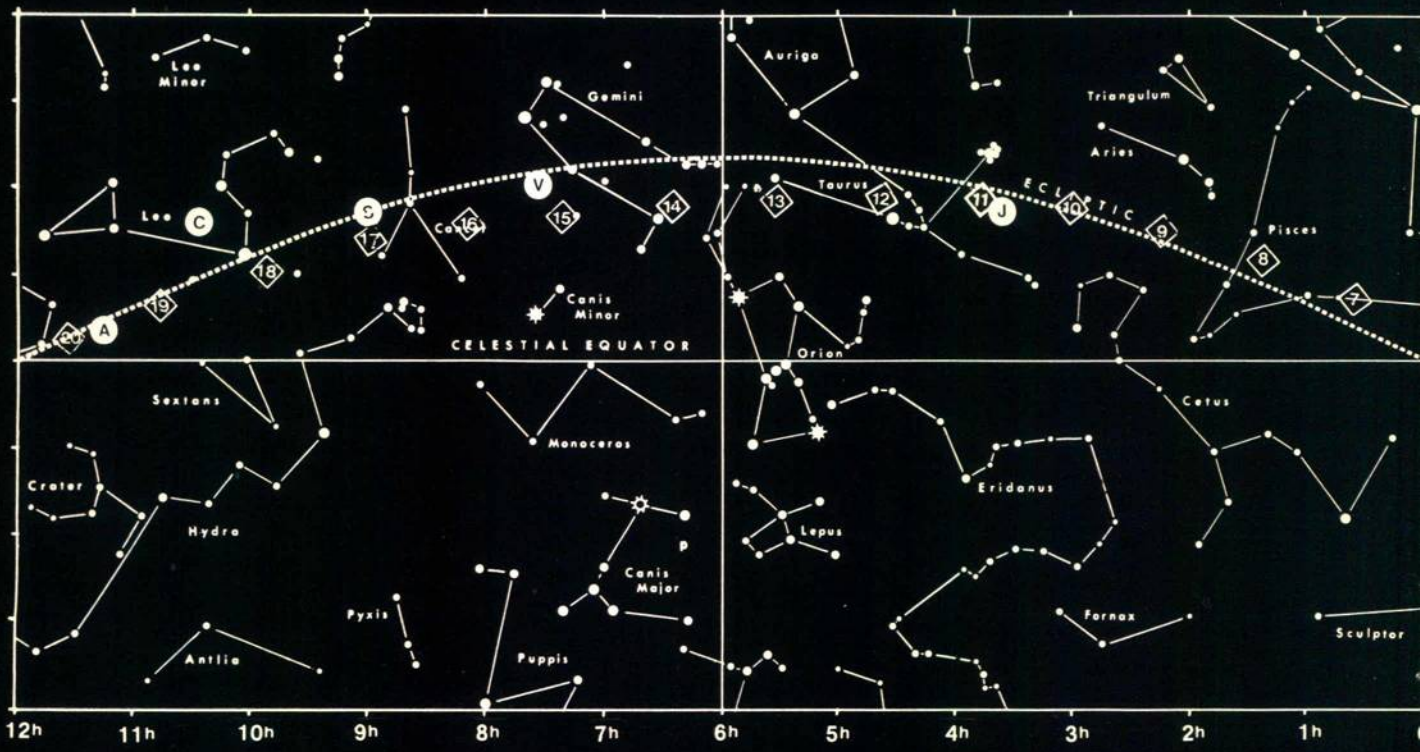
The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

Ⓢ Saturn

Oct.	1	15
R.A.	9h06m	9h11m
Dec.	+17°12'	+16°53'
Mag.	+0.6	+0.6

Ⓤ Uranus

Oct.	15
R.A.	14h17m
Dec.	-13°17'
Mag.	+5.7


Leo Minor
Gemini
Auriga
Triangulum
Aries
Leo
C
S
V
Cancer
Taurus
ECLIPTIC
J
Pisces
Canis Minor
CELESTIAL EQUATOR
Orion
A
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Sextans
Monoceros
Cetus
Crater
Hydra
Eridanus
Lepus
Canis Major
Pyxis
Fornax
Sculptor
Antlia
Puppis
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec. = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag. = magnitude, a

October 1976

Ⓥ Vesta

Oct.	1	15
R.A.	7h17m	7h32m
Dec.	+19°59'	+19°44'
Mag.	+8.3	+8.1

Ⓙ Jupiter

Oct.	1	15
R.A.	3h56m	3h52m
Dec.	+19°14'	+19°02'
Mag.	-2.2	-2.3

Ⓨ Venus

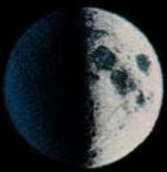
Oct.	1
R.A.	14h19m
Dec.	-13°55'
Mag.	-3.4

Ⓩ Venus

Oct.	15
R.A.	15h26m
Dec.	-19°32'
Mag.	-3.4

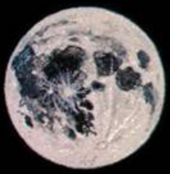
Ⓟ Pluto

Oct.	15
R.A.	13h08m
Dec.	+10°32'
Mag.	+14



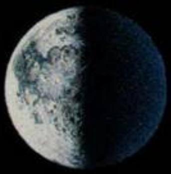
First Quarter

October 29



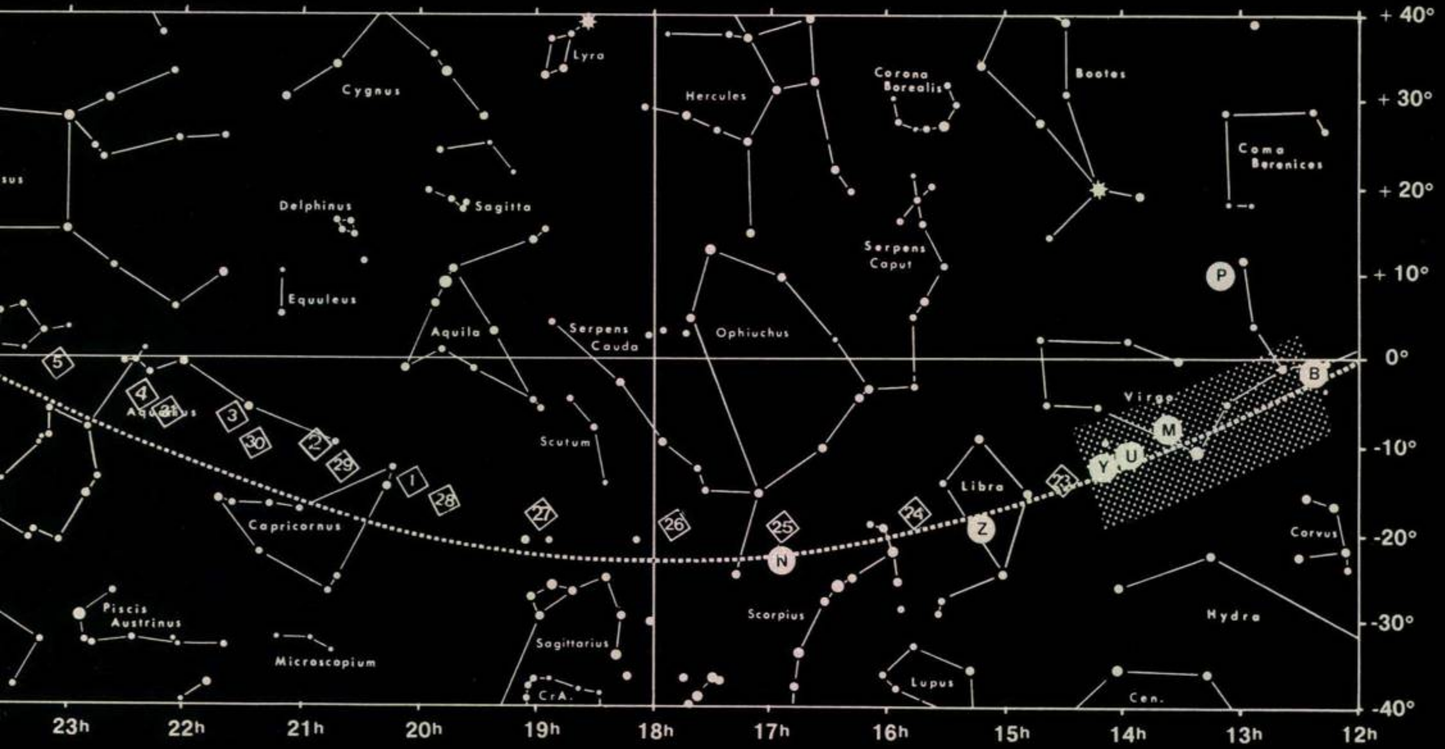
Full Moon

October 7



Last Quarter

October 15


+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
Lyra
Cygnus
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Serpens Caput
Equuleus
Aquila
Serpens Cauda
Ophiuchus
Virgo
Aquarius
Scutum
Libra
Capricornus
Corvus
Scorpius
Hydra
Piscis Austrinus
Sagittarius
Microscopium
Lupus
CrA.
Cen.
P
B
M
Y
U
Z
N
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

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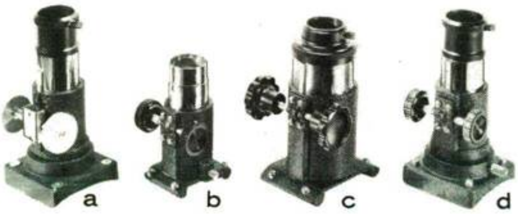

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STAR DOME

OCTOBER

by

James Mullaney and Henry J. Phillips

Each of the four seasons has its own special landmark among the stars. In winter, we see the great circle of first magnitude stars encircling the Milky Way, containing a great many clusters and nebulae. Spring's diamond of Virgo holds the largest known cluster of galaxies, and the summer triangle is set upon one of the richest regions of the summer Milky Way. Reaching the meridian this month is autumn's configuration, the Great Square of Pegasus, which contains . . . nothing. No bright stars, clusters, nebulae, galaxies or anything else of note can be found inside the borders of the Great Square. The four stars comprising it have the stage to themselves.

Another difference between the stars of the Square and those that form the other seasons' figures is the relative obscurity of the Square stars' names. Everyone knows which stars compose the great circle or the summer triangle, but not many people are aware that the Great Square's four stars also have individual names.

Let's rectify this situation at once. In the upper right corner of the Square is Scheat (Beta Pegasi), shining at magnitude 2.61. The name is from the Arabic Al Sa'id, the "upper part of the arm" — referring to the foreleg of the horse that the constellation Pegasus represents. Although Scheat is the name by which Beta is usually known today, an alternative title is Menkib, also from an Arabian word meaning "horse's shoulder".

At lower right is Alpha Pegasi, named Markab (Arabian for "saddle"). We immediately see that the saddle is placed south of the foreleg instead of above it. But there's no reason to suppose that the saddle has fallen from the horse's back, as Pegasus is placed upside down in the sky for unknown reasons. Only Hercules, among the other constellations, has this topsy-turvy orientation. Markab, at magnitude 2.57, is almost exactly as bright as Scheat.

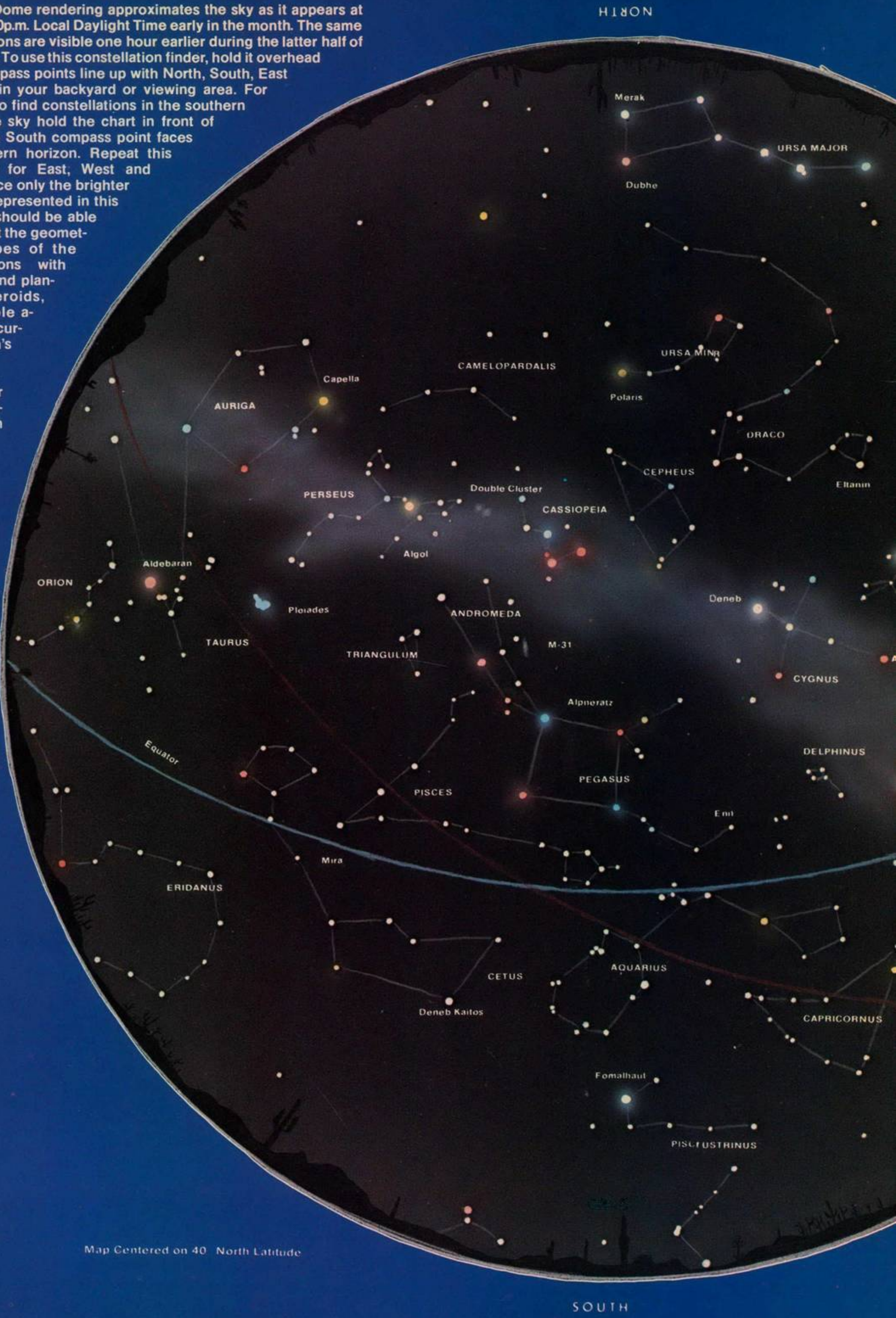
The dimmest member of the square — magnitude 2.87 — is Algenib (Gamma Pegasi); the title is derived from Al Janb, the "side". Located at lower left of the square, Algenib is almost exactly on the Pegasus/Pisces border.

Finally, at upper left, is the one member of the Square whose name is reasonably well known. This is Alpheratz, brightest of the four stars, at magnitude 2.15. This star was known to the Arabians as Al Surrat al Faras, the "horse's navel". Today Alpheratz does not belong officially to Pegasus, but falls within the borders of the neighboring constellation Andromeda — hence its designation as Alpha Andromedae. Formerly, however, the star was considered as belonging to both constellations, marking Andromeda's head as well as Pegasus' navel. This may have been one reason why it was given to Andromeda when the International Astronomical Union assigned the official constellation boundaries in 1930; it may have been thought that Andromeda could less afford to lose her head than the horse his belly button.

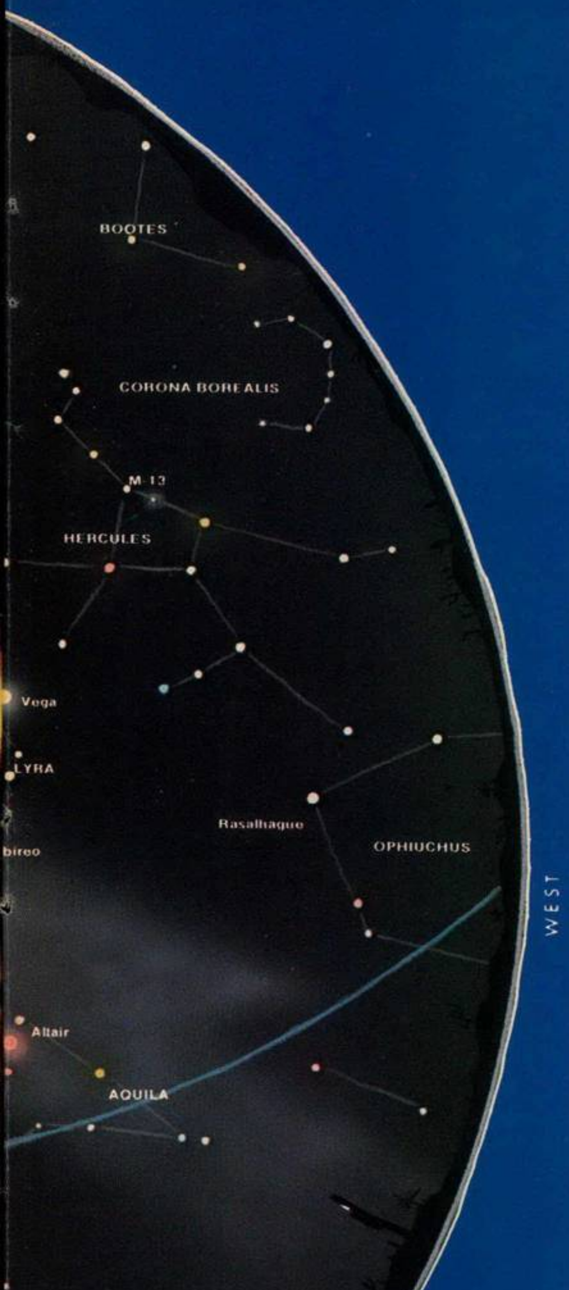
Pegasus is a huge constellation — seventh largest in our skies — and although the Square is its most distinguishing feature, it does not contain Pegasus' brightest star. That honor goes to Enif (Epsilon Pegasi), located well to the west of the Square, not far from the small groups Delphinus and Equuleus. Enif's magnitude is 2.15, and it is a giant star (spectral class K2). It marks the tip of the horse's nose.

Who or what *is* Pegasus, this upside-down horse? In Greek mythology, Pegasus was a pure white, powerful winged horse with a very strange genealogy. He sprang fullgrown from the blood of Medusa, a monstrous woman with snakes for hair, after she was beheaded by Perseus. Some writers have taken this information and gone on to incorporate Pegasus into the well-

This Star Dome rendering approximates the sky as it appears at about 11:30p.m. Local Daylight Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 68.


NORTH
Merak
URSA MAJOR
Dubhe
CAMELOPARDALIS
URSA MINR
Polaris
Capella
AURIGA
DRACO
CEPHEUS
Eltanin
PERSEUS
Double Cluster
CASSIOPEIA
Algol
Aldebaran
ORION
Pleiades
ANDROMEDA
Deneb
EAST
TAURUS
TRIANGULUM
M-31
CYGNUS
Alpheratz
Equator
DELPHINUS
PISCES
PEGASUS
Enif
Mira
ERIDANUS
AQUARIUS
CETUS
Deneb Kaitos
CAPRICORNUS
Fomalhaut
PISCIS AUSTRINUS
SOUTH

Map Centered on 40 North Latitude



Map by Adolf Schaller

known Perseus/Andromeda story, stating that Perseus was the rider (or in some cases, even the owner) of Pegasus. Actually, Pegasus has nothing further to do with Perseus — but he did take part in another adventure involving a different monster.

Bellerophon was a Greek youth who was accused of attempting to seduce his uncle's wife. The accusation was actually made by the wife herself, who had been frustrated in her own attempt to seduce her nephew. The uncle sent Bellerophon to a neighboring kingdom with a secret message for the king — the message simply being, "Kill the bearer." (Kings frequently did little favors like this for one another.) Rather than kill Bellerophon directly, the king sent him to slay the Chimera, feeling that, in this way, the youth would do himself in.

The Chimera was a hideous beast — part lion, part goat and part snake — that was ravaging the country. Bellerophon, learning in a dream that he could kill the monster only with the aid of Pegasus, successfully bridled the horse (who had never previously been ridden). Seated on Pegasus' back, he was able to shoot the Chimera with arrows, keeping away from its teeth and claws until it died.

All would have been fine, except that at this point Bellerophon decided to ride Pegasus to the top of Mount Olympus and take his place among the gods. Halfway up the mountain, however, Pegasus, realizing his rider's sacrilegious intention, threw him from his back and continued up to Olympus alone. He became the bearer of Zeus' thunderbolts, and was afterwards placed in the sky. But the Greeks still gave no explanation as to why he was put there upside down. In addition, only the front part of the horse got into the sky; Pegasus' hind legs are missing.

Scheat and Markab, in Pegasus' Great Square, point south directly toward Fomalhaut, autumn's only first magnitude star and the brightest star in the constellation Piscis Austrinus, the southern fish. The star's name is from the Arabic Fum al Hut, meaning the "fish's mouth". The name should therefore be pronounced Fom-al-hawt and not (as is sometimes supposed) Fo-ma-lo, as if it were a French word. In ancient Persia, Fomalhaut was one of the four royal stars, the guardians of heaven.

The rest of the fish consists of dim stars, and in old maps, it is depicted as swallowing the stream of water spilling from the overflowing jug held by Aquarius, the water bearer. Since fish drink little — if any — water, the pose could only have been suggested by the arrangement of stars in this area and not by nature itself.

According to ancient legend, the southern fish was the parent of the two in the zodiacal constellation Pisces. It is one of the "watery" constellations discussed here last month; others include Capricornus, Aquarius, Pisces, Cetus and Eridanus, making the whole southern autumn sky a sort of celestial sea.

To Arabian astronomers, Piscis Austrinus was larger than it is today; at that time it included the stars of Grus, the crane, which lies just south of the fish. All but invisible to most northern observers, Grus becomes more prominent farther south, and is quite bright by the time the observer reaches the latitude of Mexico City.

It is often stated that Grus is an invention of the 17th century astronomer Johann Bayer, who introduced the constellation with several others in his famous 1603 atlas, the **Uranometria.** Bayer himself, however, specifically gave credit for the new southern groups to several navigators who explored the New World and the southern seas during the 16th century. Nevertheless, Bayer was responsible for their first publication, and since the **Uranometria** was a highly respected volume acclaimed by the scientists of the time, the new constellations were soon universally accepted.

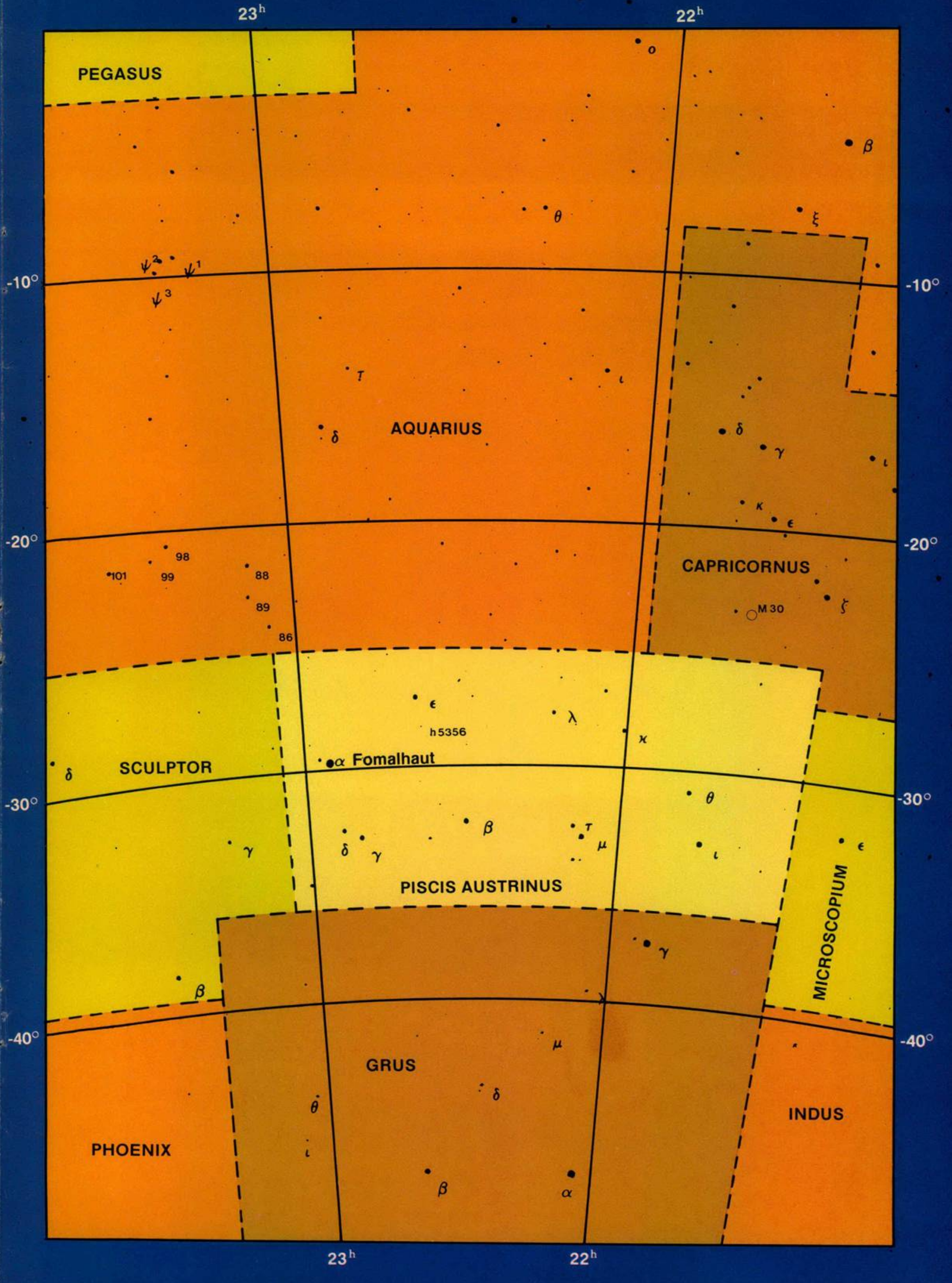
Grus is the most northern of the so-called Bayer group, and is one of a flock of "Bayer birds" that also includes Phoenix the firebird, Pavo the peacock, Tucana the toucan, and Apus the bird of paradise. All these are southern circumpolar constellations except Phoenix, which rises about as high as Grus does, a month later.

Grus' two second magnitude stars are named Al Na'ir and Al Dhanab. The former name merely means the "bright one", while the latter means the "tail"; it comes from the same root word as Deneb, the tail of Cygnus the swan. The crane's neck is formed by a string of stars including Delta, Mu, Lambda, and third magnitude Gamma, and we can easily imagine the hungry crane greedily reaching for the southern fish, which swims frantically away in the opposite direction!

Close-Up

Piscis Austrinus/Grus Region

During October, far south of the Great Square of Pegasus and low on the southern meridian, lies Piscis Austrinus, the southern fish. This constellation contains mostly dim stars, but it is the proud possessor of the


23h
22h
PEGASUS
o
β
θ
ξ
ψ2
ψ1
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-10°
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AQUARIUS
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ε
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98
101
99
88
89
86
CAPRICORNUS
M30
ζ
ε
λ
h5356
κ
δ
SCULPTOR
α Fomalhaut
-30°
-30°
θ
β
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μ
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δ
γ
ι
ε
PISCIS AUSTRINUS
MICROSCOPIUM
γ
β
-40°
-40°
μ
GRUS
δ
θ
INDUS
PHOENIX
ι
β
α
23h
22h

blue-white luminary Fomalhaut — the most southerly of the first magnitude stars visible from midnorthern latitudes. A line drawn from Beta (β) through Alpha (α) Pegasi (on the western side of the Great Square) and extended downward points directly to this star. Fomalhaut rises simultaneously with Capella in the northeast; their appearance is a stellar signal that autumn has arrived and winter is not far behind.

The figure of the fish is neatly outlined by a curved loop of stars containing Epsilon (ϵ), Fomalhaut, Delta (δ), Gamma (γ), Beta, Mu (μ), Iota (ι) and Theta (θ). With a small stretch of your imagination, you can see it with the unaided eye or wide angle binoculars on a dark night.

Piscis Austrinus is fairly small in area, covering only 245 square degrees and ranking 60th in order of size of the 88 constellations. Barns, from his site in southern California, tells us that this group "lies too low on the horizon in our latitude to encourage extensive observation", but goes on to say that Fomalhaut "is a very sightly autumn visitant from the southland". As with several other isolated bright stars, this object's radiance seems enhanced by the comparative darkness of the stellar background here.

Although words like "dull" and "uninteresting" are often used to describe Piscis Austrinus, it does contain some worthy telescopic subjects.

Should you succeed in tracing out the southern fish from your location, try pushing farther south to see if you can make out its neighbor Grus, the crane. Badly obscured by horizon haze in our latitudes, Grus is actually quite prominent if you travel farther south where it rises higher in the sky. Its brightest units are third magnitude Gamma (near the Piscis Austrinus border) and second magnitude Alpha and Beta. The latter two are on or near the horizon, depending on your exact latitude; at 40 degrees north, these two stars are less than three degrees above the horizon at meridian transit and are considerably dimmed by atmospheric absorption. Even though the crane contains a number of interesting double stars and galaxies, Grus stacks up poorly in the telescope due to its low declination.

There is, however, an unusual tendency for the stars here to pair off, or form groups. These make fine binocular objects, beginning with an unnamed triple just one degree southeast of Gamma Gruis. Other pairs are formed by the stars Mu 1 and 2, Delta 1 and 2, Sigma (σ) 1 and 2 and Pi (π) 1 and 2. Even Alpha and Beta, with nearly identical magnitudes of 2.16 and 2.24, can be considered a wide matched pair! These all hardly seem due to mere chance alignment; they may have a common origin, such as a widely scattered cluster.

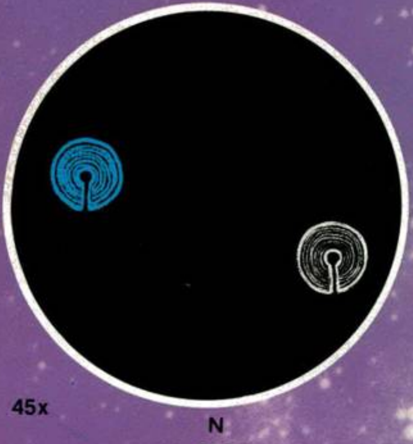
Since Piscis Austrinus and Grus lie so near the horizon, whatever observations you attempt of this month's region — whether with the unaided eye, binoculars or telescope — should be undertaken on dark transparent nights without interfering moonlight. Should you live near a large metropolitan area, find a site *south* of the city itself. This places the inevitable glow from lights and pollution to the north, well clear of your line of sight.

Fomalhaut

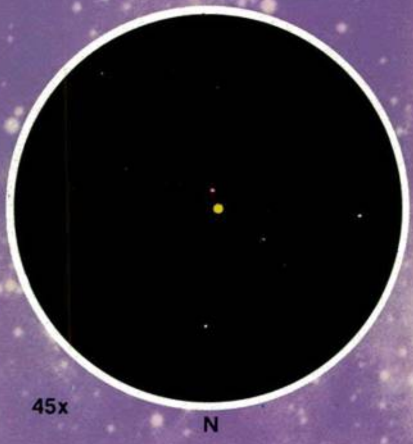
The best starting place for telescopic exploration of Piscis Austrinus is its glittering first magnitude leader, Fomalhaut. It shines with an icy blue color in isolated splendor amid an apparent stellar desert, leading to its occasional nickname, the "solitary one".

Its lovely pure tint (spectral type A3) is frequently broken by prismatic flashes; in other words, it "twinkles harder" than other stars due to compound atmospheric turbulence from multiple air currents so near the horizon. Rather than cursing this state of affairs, you can use it for a spectacu-

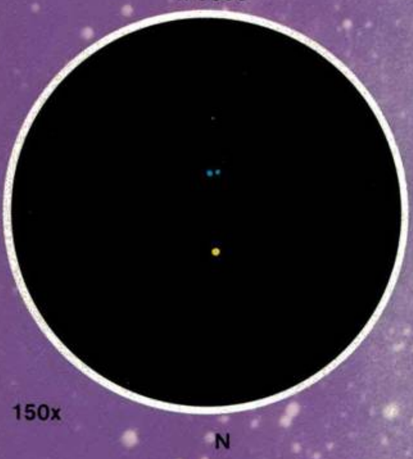
Fomalhaut and field star



Beta Piscis Austrini



h 5356



Top left: Fomalhaut is the brightest star in Piscis Austrinis, and the sole first magnitude star of autumn. A four inch reflector outside of focus will reveal it and a field star, between which can be seen flickering caused by atmospheric turbulence. The field of view in the drawing is one degree. Top right: Beta Piscis Austrini, as seen through a three inch refractor, presents contrasts of both magnitude and color. The brighter star is yellowish and magnitude 4.4; the dimmer companion (magnitude 7.9) is purple. In this drawing, too, the field is one degree. Left: The triple star system h 5356 is seen here through a five inch Schmidt-Cassegrain. The yellow star actually has no connection with the tight pair of blue stars. Drawings by James Mullaney.

Table of Selected Objects — Piscis Austrinus/Grus Region

Object	Type	Mag.	Size/Sep.	R.A. (1950)	Dec.
PISCIS AUSTRINUS					
*η(Eta)	★2	5.8,6.8	1.6"	21^h58^m	-28°42'
*β(Beta)	★2	4.4,7.9	30"	22^h29^m	-32°36'
NGC-7314	Sp	11	4'x2'	22^h33^m	-26°18'
*h 5356	★3	6.3,7.4,7.9	87",3"	22^h37^m	-28°36'
γ(Gamma)	★2	4.5,8.1	4"	22^h50^m	-33°08'
*Fomalhaut	B1	1.3	—	22^h55^m	-29°53'

*Detailed in Close-Up

★2 = Double Star
★3 = Triple Star
B1 = Blue Star
Sp = Spiral Galaxy
Mag. = Magnitude
Sep. = Separation

lar demonstration of atmospherics at the telescope.

Just northeast of Fomalhaut is a fifth magnitude field star. Using a low power, wide-angle eyepiece that gives at least one degree of apparent field, center both objects in your telescope. Then place the eyepiece outside of focus by perhaps an inch. The resulting extrafocal images are shown in our drawing, which was made with a reflector having a single vane diagonal holder. Both the diagonal mirror and vane are seen silhouetted against the images.

This technique can be used to deduce something about the state of the atmosphere and the thermal environment of the telescope. To demonstrate this, a bright star low in the sky, where seeing is often poor, serves best. Thus, Fomalhaut is ideal for the following observation.

With the eyepiece out of focus as indicated, both Fomalhaut and its fainter neighbor will display disks of the same apparent diameter but different brightness. Now, stare at the center of the field of view. If seeing is poor, you will behold a startling prismatic flickering or flashing of the extrafocal star images! At times this will occur in unison (both images bright or faint together), while even moments later it may happen out of phase (one image bright, the other dark) — all depending on the size and frequency of the turbulence along the line of sight at the moment. Here, then, is a seeing indicator provided by nature in the form of a stellar interferometer!

With experience, the actual seeing cells can be distinguished and even focused on, permitting the observer to tell if poor seeing is truly atmospheric or simply the result of thermal currents near the ground — or even within the telescope itself. As with terrestrial objects, the more distant the disturbance from the telescope, the farther *in* the focus will be.

Here is a sight sure to intrigue and interest even seasoned observers; try it yourself the next clear night. Does the effect vary as the stars rise, transit the meridian, and set? Is it different with the approach of a cold or warm front?

We are fortunate in having a convenient bright test star for observing this effect. Lovely Fomalhaut, shining at magnitude 1.3, lies just 23 light-years from us. It displays an appreciable proper motion, causing it to move the moon's diameter across the sky in about 6,000 years.

Beta (β) Piscis Austrini

Six degrees southwest of Fomalhaut is fourth magnitude Beta, a fine double star for small telescopes. Its components are 4.4 and 7.9 magnitudes, separated by a roomy 30 seconds of arc. The pair is easy to detect in a three or four inch scope at 45 power and presents a nice magnitude-color contrast, as our drawing shows. The brighter star looks yellowish-white or cream, with an occasional tinge of orange added by poor seeing. Its companion, lying to the south, appears bluish-purple in hue. Color estimates such as these, made of stars at low declinations, are often difficult and require patient watching on steady nights.

Descriptions by the classic writers of southern objects such as Beta are almost totally lacking in the literature. This is no surprise when we consider that observers like Herschel, Smyth and Webb worked from the high latitude of the British Isles. Deep sky enthusiasts, therefore, have an opportunity to tread on new ground and provide modern descriptions of these neglected subjects.

The two components of Beta comprise an optical pair rather than a true physical binary system. The fainter star is more distant than the brighter one, and both simply happen to lie in the same line of sight in space. It seems ironic that one of the few notable pairs in this sparse region isn't a real double star at all!

h 5356

An obscure but attractive triple star — providing an example of both an optical and physical pair within the same system — is located slightly more than a degree south of fourth magnitude Epsilon Piscis Austrini (itself four degrees northwest of Fomalhaut). Having no other designation than h 5356, the system can readily be swept up in a good finder as a double star.

These wide components are 6.3 and 6.8 magnitudes with a separation of about 90 seconds, and were already known when Sir John Herschel (William's son) discovered that the fainter member is itself a close double star. The pair consists of seventh and eighth magnitude suns, presently a tight three seconds apart. This duo is a true binary with both stars in orbital motion about a common center of gravity. The distant 6.3 star, however, appears to be merely a field star unrelated to the other two.

Colors for this system are orange for the "primary" and blue-white for the companions as shown in our drawing. All three can be seen in a four inch telescope at about 150 power, but higher magnification is required for a good split — if seeing will permit its use. Larger apertures increase resolution but are also more sensitive to atmospheric conditions (especially important for this month's region). The five inch catadioptric used for the drawing seems the optimum instrument for this object.

Today the binary in h 5356 is situated nearly due south of the optical object at a position angle of 180 degrees, while its close companion lies roughly due east (position angle 90 degrees). Back in Webb's time, the close pair was at 160 degrees in relation to the field star. The binary's separation was at least one second of arc greater, and its position angle then measured 58 degrees. These changing figures are due to orbital motion in the binary and field movement of the optical star.

Eta (η) Piscis Austrini

If you succeed in resolving h 5356, why not try an even closer pair? A good challenge is sixth magnitude binary Eta Piscis Austrini, which may be found by setting your finder one degree north of Fomalhaut and sweeping one hour (15 degrees) due west.

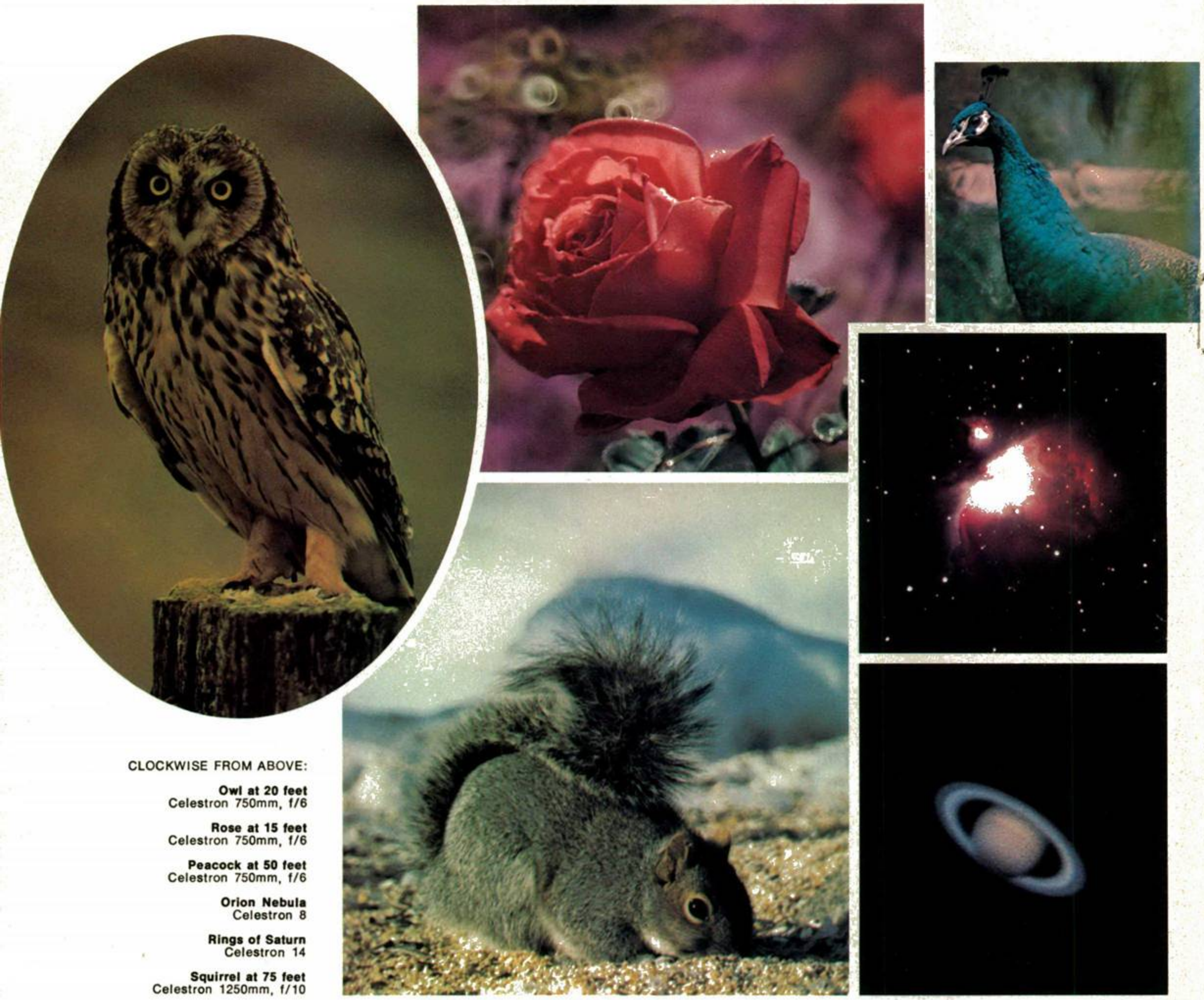
The components here are of magnitudes 5.8 and 6.8, both appearing bluish-white in color. The position angle and separation show slow increases; the present values are estimated at 120 degrees and 1.6 seconds. A good three or four inch telescope at about 100 power will elongate the pair; at twice that figure, it will be cleanly resolved — provided the air is steady.

Few current measurements exist for doubles like Eta. Indeed, many visual binaries around the sky are going unobserved; there are only a handful of active professional observers in the field today, and they can't do everything because of the vast numbers of binary systems that have been discovered.

Stars do not stand still. With each passing year, priceless and often unrepeatable observations are being lost as many pairs (like Eta Piscis Austrini) go unwatched. The well equipped amateur who can build or obtain a filar micrometer could quickly join the ranks of the professional astronomer in this important and rewarding task. Especially welcome would be measurements of carefully selected pairs, made with modern catadioptric telescopes in the hands of skilled and patient observers.

For those who truly love the stars, even a dull looking sky area like this month's region holds charm and fascination. Why this should be so — or, indeed, why we should look to the stars at all — is something of a mystery. Many may feel that the answer lies in a well-known quote by Eric Hoffer:

"I always felt man is a stranger on this planet, a total stranger. I always played with the fancy: maybe a contagion from outer space is the seed of man. Hence, our preoccupation with heaven — with the sky, with the stars, the gods — somewhere out there in outer space. It is a kind of homing impulse. We are drawn to where we come from."



CLOCKWISE FROM ABOVE:

Owl at 20 feet
Celestron 750mm, f/6

Rose at 15 feet
Celestron 750mm, f/6

Peacock at 50 feet
Celestron 750mm, f/6

Orion Nebula
Celestron 8

Rings of Saturn
Celestron 14

Squirrel at 75 feet
Celestron 1250mm, f/10

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